302 AMAZING IMAGES & CUTAWAYS INSIDE

THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS

ENVIRONMENT TECHNOLOGY TRANSPOR RY SPACE

INSIDE

SCIENCE OF CUTE
Why we are programmed to find baby mammals adorable

HUMANOID ROBOTS
The real-life robo-sidekicks who only want to serve

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AEROBATIC DISPLAYS

THE AMAZING TECH BEHIND THE DEATH-DEFYING STUNTS

+LEARN ABOUT

- SUNGLASSES
- GALAXIES
- WASPS
- FACE MASKS
- LEAVES
- TINNITUS
- SAFES
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ISSUE 75

WELCOME

The magazine that feeds minds!

Page 38
Can robots really bond with humans?

Summer on the south coast means airshows and ice creams. Thousands gather to catch a glimpse of the world famous Red Arrows, and **How It Works** is lucky enough to have front row seats. Outside the office window, the sound of jet engines rumble and the skies are graffitied with loop-the-loops and cheeky hearts. Magazine production grinds to a halt as everyone grabs their phones to capture the magic. It's definitely an Instagram moment when nine aircraft perform perfectly synchronised stunts at 600mph (965km/h) with just six feet (1.8 metres) between them.

In the UK, the Red Arrows demonstrate the professional excellence of the Royal Air Force, inspiring future generations of pilots and officers, while over in America, the Blue Angels do the same for the US Navy and Marine Corps. We chatted to pilots from both sides of the pond, who revealed what it takes to become part of these world famous squadrons. Airshows are a testament to human endurance and expert technology, and we're proud to feature them on the cover for the first time.

Enjoy the issue!

Jodie

Jodie Tyley
Editor

Meet the team...

Andy
Art Editor
Of all the animals used by us humans in war, none are more impressive or as dangerous than the elephant.

Siobhan Maguire
Production Editor
Learning all about the science of cute was the best welcome to **How It Works** magazine. Now I want a kitten!

Phil
Staff Writer
After writing the aerobatic displays feature this month, I'm even more excited to see the Red Arrows perform this summer.

Jackie
Research Editor
FINALLY. A feature that allowed me to watch cat videos on YouTube! All in the name of science, of course.

Jo
Assistant Designer
It's been a colourful month, and after reading our why is the sky blue feature, I'm more than ready to enjoy the lovely summer weather!

Jo
Features Editor
Although I have now answered 51 questions about colour, I still don't know why on Wednesdays we wear pink.

What's in store

Check out just a small selection of the questions answered in this issue of How It Works...

How do face masks work? **Page 32**

Why is Lake Natron bright pink? **Page 56**

How do pilots pull off such daring stunts? **Page 12**

How did the smartwatch evolve? **Page 46**

What is the deadliest planet in the Solar System? **Page 66**

How were elephants used in war? **Page 78**

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Meet the experts...

Laura Mears
Pixar's *Inside Out* features Emotions that live inside your noggin and dictate how you feel. These are actually neurotransmitters personified, and you can read all about how they affect your mood on page 37.

Alicea Francis
This month, **All About History** magazine's Alicea takes us on a tour of the creepiest chapel around (page 76). She also reveals how to tie a Roman toga, and even models one for us!

Tim Williamson
Tim from **History Of War** magazine loves writing about battles, scoffing pistachio nuts, and the USA. Two out of three isn't bad this issue as he delves into the American Civil War on page 70.

Lee Sibley
The Editor of **Total 911** gets behind the wheel of a professional racing car simulator and reveals how this technology is helping the pros to tackle any track.

Ceri Perkins
Stephen Hawking warned that AI could spell the end of mankind, but robo-butlers and pets you don't need to clean up after does sound quite appealing, over on page 38.

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REGULARS

A garden across London's Thames?

The bridge with a difference offers a picturesque commute

Among the towering skyscrapers and bustling streets of England's capital city, a new leafy green oasis is due to be constructed. The Garden Bridge will give pedestrians a more scenic route across London's River Thames, with a footpath that weaves through an expansive garden landscape. Around 2,500 square metres (26,910 square feet) of the bridge will feature 270 trees, 2,000 shrubs, hedging plants and climbers, over 22,000 hardy perennials, ferns and grasses and 64,000 bulbs. Each species has been selected specifically for its resilience and suitability for this environment, and soil scientists have ensured the right conditions for different species can be achieved. At the time of writing, the project is still waiting final approval, but it's hoped construction will begin in 2016 and it will open to the public in 2018, providing a leafy link between north and south London.

Super-strength protective skin

The carbon steel feet and underside of the Garden Bridge will be coated in copper-nickel alloy, a material also known as cupronickel that is made mainly of copper, a smaller percentage of nickel and some iron and manganese. It is typically used to coat boats and oil rigs because of its excellent resistance to seawater corrosion, so will help to prevent the bridge from rusting. It will also help to improve the strength of the bridge and make for a visually appealing structure thanks to its warm colour. More than 240 tons of cupronickel will be required to cover the 366-metre (1,201-foot) walkway, but its protective qualities will make the bridge very low maintenance.

The base of the Garden Bridge will have a protective copper-nickel alloy skin

The Garden Bridge will provide year-round colour and attract a diverse range of wildlife

The idea for the Garden Bridge was first conceived by British actress Joanna Lumley

New microscopic monsters discovered

The oceans' plankton is far more diverse than previously thought

While spending five years sailing the world's oceans, an international team of researchers collected 35,000 samples of microorganisms, including many species that were previously unknown to mankind. These microscopic beings, commonly known as plankton, live in the upper layer of the ocean and, via photosynthesis, produce over half of the oxygen we breathe. Plankton are a vast group of different species, including viruses, bacteria, single-celled organisms and other tiny plants and creatures. Scientists are now studying the samples collected by the Tara Expedition to help them better understand this rich underwater ecosystem.

Weird and wonderful new creatures have been discovered by the Tara Expedition

Robots win gold

The Robo-Olympics tests machine intelligence

Teams from all over the world have put their robot creations to the test as part of the DARPA Robotics Challenge. Each robot had to complete eight tasks simulating disaster response scenarios, including driving alone, walking through rubble, tripping circuit breakers, turning valves and climbing stairs. Only three out of the 23 teams managed to complete all eight challenges, with Team KAIST from South Korea taking the £1.3 million ($2 million) first prize. Their robot, called DRC-Hubo, managed to complete the course in 44 minutes and 28 seconds.

Team KAIST's DRC-Hobo robot managed to open a door as part of the challenge

Solar spaceship aces first mission

Is flight by light the future of cheap space travel?

The citizen-funded project LightSail has successfully deployed its solar sail in low-Earth orbit. The spacecraft doesn't require any fuel, instead using the Sun's energy as a method of propulsion. Light is made of packets of energy called photons, which have momentum. As the photons reflect off of the spacecraft's large mirrored sails, this momentum is transferred, pushing on the sail to result in small but continuous acceleration. LightSail's successful first test mission will now pave the way for its successor in 2016, which will fly beyond Earth's orbit and into the Solar System.

LightSail launched their first prototype aboard an Atlas V rocket in May 2015

The spacecraft captured this image of its deployed solar sails in orbit

GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH

LHC broke the atom smashing record

After a two-year hiatus during which it was extensively upgraded, the Large Hadron Collider (LHC) has broken the record for smashing together sub-atomic particles. The LHC is now capable of reaching energies twice as high as it previously could, which scientists believe will open the door to realms of physics humanity has yet to explore. In the years to come, the study of hidden dimensions and dark matter is the main target for CERN's researchers.

Infections can lower your IQ

A study has shown that there is a clear correlation between infection levels and cognitive impairment. Researchers found that all types of serious infection, not just those that affected the brain, lowered an individual's IQ. By discovering this link, scientists hope to learn more about the connection between the immune system and the development of mental disorders.

Bacteria help repair damaged siblings

An interesting discovery has been made which suggests that certain soil bacteria can help repair other bacteria that are damaged. This is possible due to the process of outer membrane exchange (OME), which is commonplace within the social behaviour of soil bacteria. This is the first time evidence of this activity has been seen, and it can be compared to the way cells in a human body adapt to heal a wound.

Drugs can be found in fingerprints

Using a new technique, scientists have found a way to identify cocaine use from a single fingerprint. This method determines whether the owner of the fingerprint has taken cocaine, rather than just identifying whether they have come into contact with the Class A drug. This was achieved by testing for cocaine metabolites such as benzoylecgonine and methylecgonine. Researchers are hopeful that this technique will have a wide range of applications in drug testing, as it is much more difficult to fake results.

Space debris will be shot with laser cannons

In 2017 scientists plan to begin the test phase of a laser cannon on the ISS that would be used to shoot down space debris. There are roughly 22,000 known objects in orbit that could threaten new and existing space missions, which could make this tool very useful in the future.

There's a new trigger for volcanic eruptions

Scientists believe they have taken a vital step in furthering their understanding of volcanic activity. By creating a scaled down volcano, researchers examined how magma rises from great depths to the surface via a multitude of fractures known as dykes and sills. They found that a pressure drop occurred when a sill formed, which they believe can cause dissolved gases to be released, resulting in the magma exploding and an eruption taking place.

There's a jet-propelled paddleboard

Paddleboarding has been gaining popularity for a while, and now inventors have created a version that makes this fun hobby even more relaxing. The built-in jet propulsion engine will push the paddleboard along at up to 3.5 knots, around 6.5 kilometres (four miles) per hour, enabling users to enjoy the view without working up a sweat.

Salmon ears contain GPS trackers

By analysing a tiny structure that grows inside their ears, scientists have been able to map the journeys of hundreds of Chinook salmon. This bone-like structure is called an otolith, which form in layers as a salmon matures. As these layers form, they trap tiny amounts of isotopes that can be traced to specific areas. Scientists hope to use this data to pinpoint where salmon migrate to, so that these areas can be protected from pollution and over-fishing too.

A levitating bulb stays lit for 22 years

This incredible levitating lightbulb works using magnets and can be operated by simply touching its wooden base. It draws power wirelessly from the charger block that it floats above via a process known as induction. If the bulb is used for around six hours a day, it will have a lifetime of 22 years, and will endlessly levitate above the charger block to keep going.

A teabag can change light lager into craft beer

If you have ever dreamt of customising your favourite alcoholic beverage, you may not have to wait much longer. A company called Hop Theory has created a type of teabag that turns standard lager into craft beer in a matter of minutes. It aims to provide the intense flavour of craft beer without the high cost and the calories, with each bag capable of flavouring four beers.

AEROBATIC DISPLAYS

THE AMAZING TECH BEHIND THE DEATH-DEFYING DISPLAYS

The Red Arrows, whose motto is "Éclat" meaning brilliance, are based at RAF Scampton in Lincolnshire

Anyone who's seen the Red Arrows or the Blue Angels perform will know why many consider these pilots to be the world's best. They execute death-defying stunts at breakneck speeds; flying low to the ground and experiencing g-forces that makes their heads feel like 20-kilogram (44-pound) balls. They manage not only to control their aircraft, but also to work perfectly in a team, pushing themselves and their aircraft to the limit.

The Blue Angels – the US Navy's flight demonstration squadron – and Red Arrows – the UK's Royal Air Force Aerobatic Team – have very interesting origins. After World War II ended, the US chief of naval operations, Admiral Chester Nimitz, was keen to maintain the high level of public interest in naval aviation. He feared that he would lose significant amounts of funding to other areas of the US Army; therefore, he devised a plan to create a flight exhibition team. Throughout the following decades, the Blue Angels flew a number of different planes, including the F6 Hellcat, the F-4 Phantom and the A-4 Skyhawk. They finally settled on the Boeing F/A-18 Hornet in 1986, the 40th anniversary of their conception, which they still use today. The Blue Angels now perform all over America, with air shows taking place between March and November.

The Red Arrows take their name from two aerobatic display teams that preceded them, the Red Pelicans and the Black Arrows. The first Red Arrow display team was formed in 1964 after concerns that aerobatic display pilots were neglecting their combat training, as they preferred to practice their stunts. The first official Red Arrows flew the Folland Gnat which had been used by the Yellowjacks in previous years. The original team flew with seven aircraft, until 1968 when they decided to adopt their now trademarked 'Diamond Nine' formation. In 1979, the BAE Systems Hawk – a modified version of the Royal Air Force's fast jet trainer – was chosen to replace the Gnat. The Red Arrows have now performed nearly 5,000 shows and celebrated their 50th season in 2014.

Death-defying displays

Find out how display pilots pull off their incredible manoeuvres with precision and coordination

Both the Red Arrows and the Blue Angels update their show routine each year, which typically lasts between 20 and 30 minutes. They prepare three different displays and choose which one to perform by examining the weather conditions. A 'full' or 'high' show will be performed in clear weather, when the cloud base is over 1,372 metres (4,500 feet) high. This allows a full, looping display to be carried out and means that even at the top of each loop, the planes will remain visible.

If the cloud base is lower than this and conditions are overcast, a 'rolling' or 'low' display is performed. When the weather is particularly bad and the cloud base is below 762 metres (2,500 feet), a 'flat' show is performed. This will include mainly flypasts and steep turns, as these are the only manoeuvres that remain visible in such conditions.

The first five Red Arrow planes (Reds 1 to 5) are the front part of the overall formation, known as 'Enid.' The remaining three planes, Reds 6 to 9, make up the rear section and are known as 'Gypo.' Reds 6 and 7 are the 'Synchro Pair,' and will perform opposition manoeuvres during the second half of the show. The Blue Angels also have a similar pair – the Blue 5 and 6.

Blue Angel 5 pilot Mark Tedrow spoke about the most challenging manoeuvre that he performs: "It's called the inverted tuck over roll which is where I'm trying to hide my plane behind Blue 6, so the crowd only see one aircraft. Last year we performed this upright, but this year we decided to make things harder and perform it inverted."

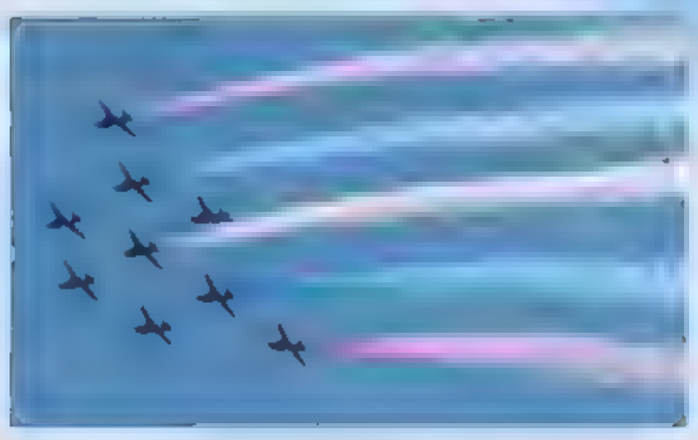
Being disciplined during a manoeuvre is vital for all display pilots. Hours of practice enable the Red Arrows to move nine aircraft as one. Red 2 pilot Mike Bowden, revealed how the Red Arrows achieve this visual feat: "There's a perfect position to be in during all manoeuvres and to achieve this we aim to triangulate a position on the Team Leader's aircraft," he explains. "We use two reference points to put us in the right part of the sky, which helps us to ensure that we don't get too close. Six feet [1.8 metres] apart is close enough when you've got nine aircraft in one vicinity."

Dye in the sky

[illegible]

The Red Arrows can produce a vapour trail for seven minutes during a 30-minute display

"The first five Red Arrows planes (Reds 1 to 5) are the front part of the overall formation, known as 'Enid'"



DISPLAY MANOEUVRES

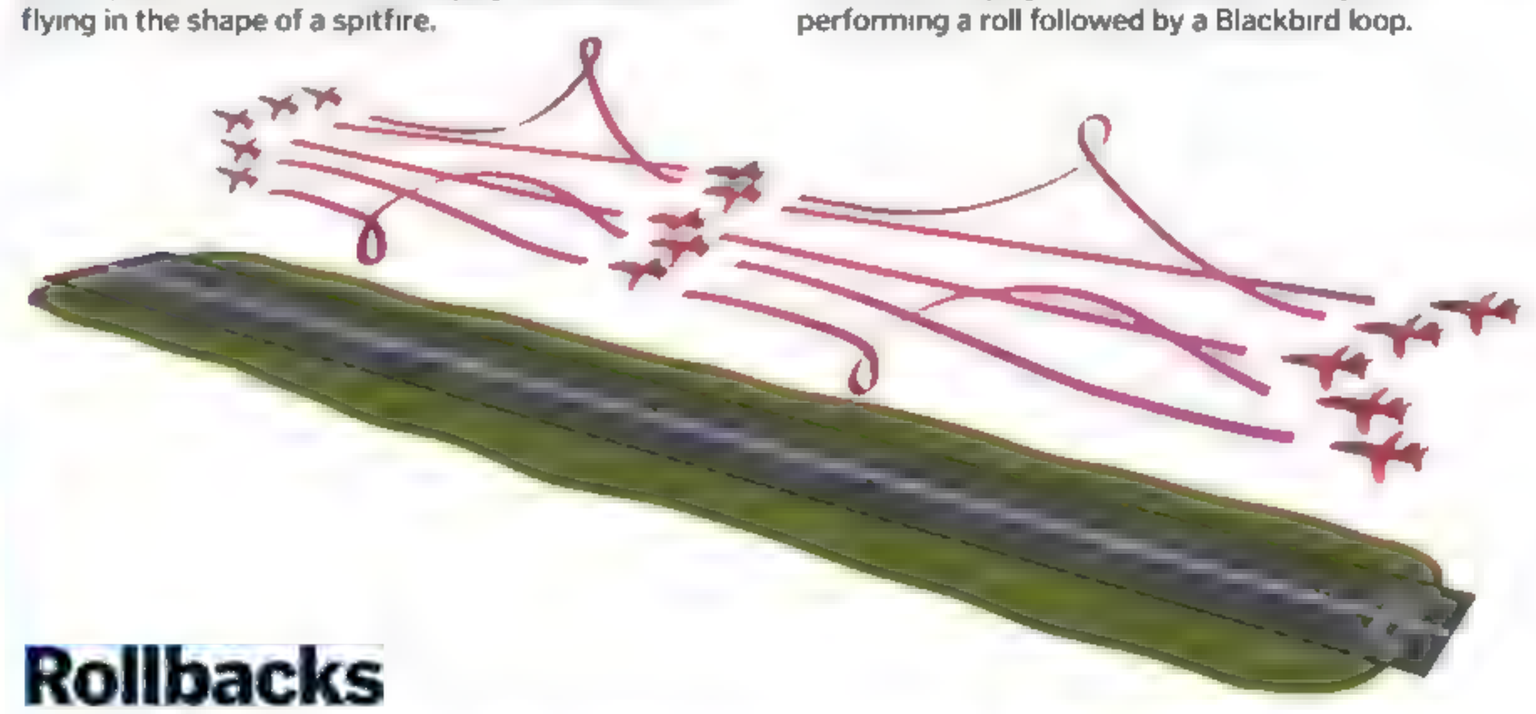
See the display manoeuvres that will be performed this year

Spitfire Reversal

In recognition of the 75th anniversary of the Battle of Britain, the 2015 Red Arrows display will feature them flying in the shape of a spitfire.

Whirlwind

The Whirlwind is a brand new manoeuvre for the 2015 Red Arrow displays and features all nine jets performing a roll followed by a Blackbird loop.



Rollbacks

Red 2 will pull out of the Diamond Nine formation and perform a full 360-degree roll around Red 4 and then himself outside of Red 4. At the same time, Red 3 will perform an identical manoeuvre around Red 5. The difficulty here is to keep the roll as tight as possible, and to time the rolls so that they are the same speed and look the same to the crowd.

Vixen Break

All planes fly directly towards the crowd, before breaking in different directions up and away from the crowd, pulling up to 7g. This is often a crowd favourite, but is one of the simplest manoeuvres to perform.

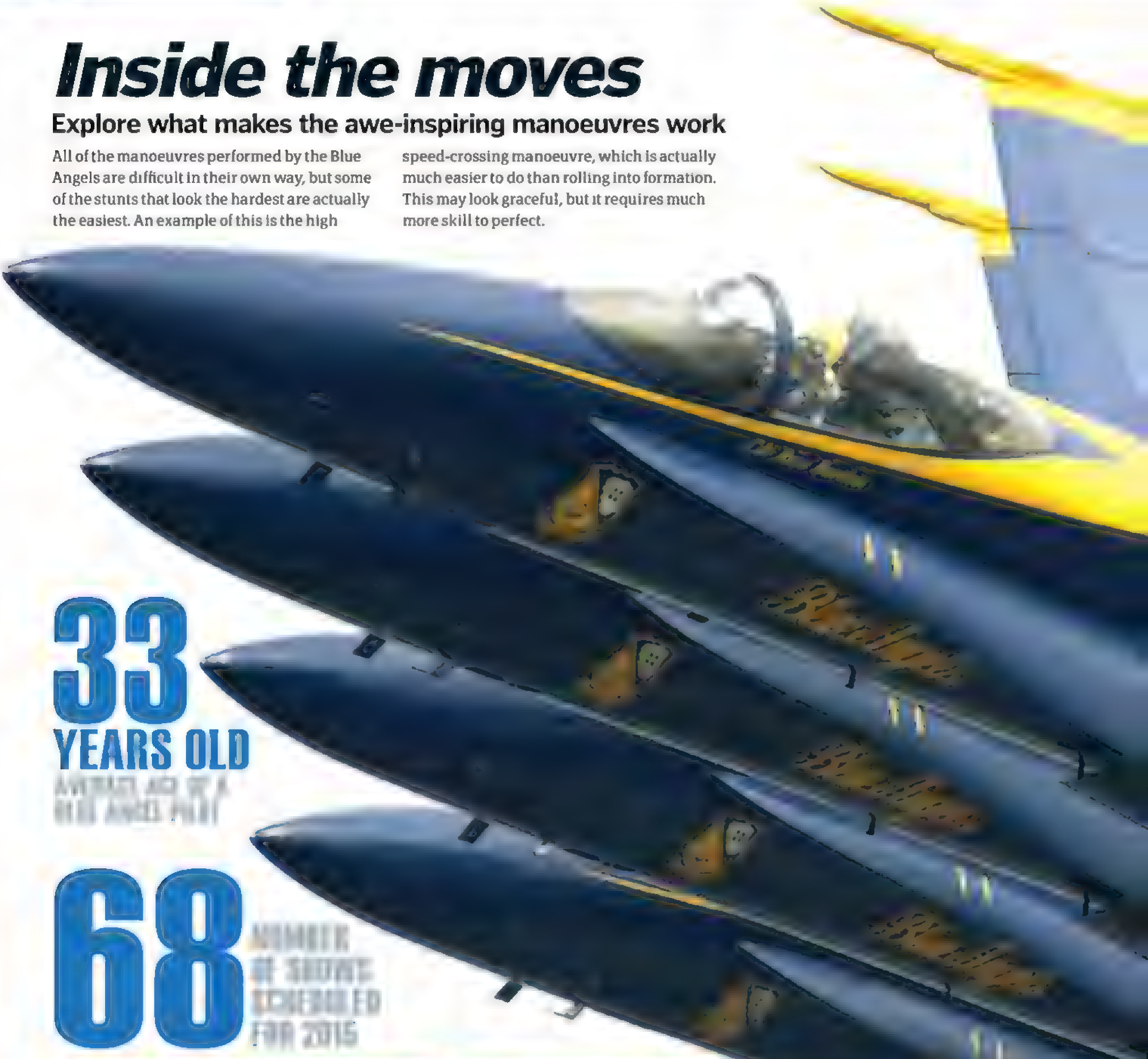
Mirror Roll

Throughout their 2015 displays, the Red Arrows will be reviving the Mirror Roll which involves Red 6 performing an inverted barrel roll at -2.5g, while Reds 7, 8 and 9 remain in formation.

Inside the moves

Explore what makes the awe-inspiring manoeuvres work

All of the manoeuvres performed by the Blue Angels are difficult in their own way, but some of the stunts that look the hardest are actually the easiest. An example of this is the high speed-crossing manoeuvre, which is actually much easier to do than rolling into formation. This may look graceful, but it requires much more skill to perfect.



33 YEARS OLD
[illegible]

68 [illegible] FOR 2015

Fat Albert

[illegible]

1200 GALLONS (4,542 LITRES) JET FUEL [illegible]

Double Farvel

This manoeuvre involves the first four Blue Angels. They perform a flypast in a very tight diamond formation while two of the planes, Blue Angels 1 and 4, are inverted.

Knife Edge Pass

To perform this manoeuvre, two planes fly towards the same point at high speed, before suddenly altering their position so they pass each other. This can be performed as low as 15.24 metres (50 feet).

Section High Alpha Pass

This is the slowest manoeuvre the Blue Angels perform, and involves two of the jets slowing to 193km/h (120mph) as they pitch the noses of their planes up to an angle of 45 degrees.

"The high speed-crossing manoeuvre is actually much easier to do than rolling into formation"

Blue Angels versus Red Arrows

Blue Angel: F/A-18 Hornet

Find out about the Blue Angel F/A-18's most important features

"Efficient and reliable communications are important for the Blue Angels," says Kyetta Penn, aviation electronics technician for the Blue Angels. "It is vital that they are able to talk to each other during a display and also to the ground staff so we know what's happening and can troubleshoot problems."

GPS is also absolutely vital so that their location can be pinpointed, while radar enables the pilots to see exactly what is going on around them. "They can make sure they are clear to carry out their display and that there are no other aircraft in their airspace," Penn adds.

Although every effort is made to ensure the pilot's safety, things can go wrong. Recently, part of Mark Tedrow's F/A-18 became detached mid-flight, calling into question the lifespan of these ageing fighter jets. He explains exactly what happened: "I was in a high-g rendezvous with the diamond to execute a manoeuvre called 'the line of our swoop' which is when part of my wing became detached," he recalls. "This is why we take seven planes to each show; I was able to land my F/A-18, jump into the spare and complete the performance." The show must go on!

15.24m (50ft)

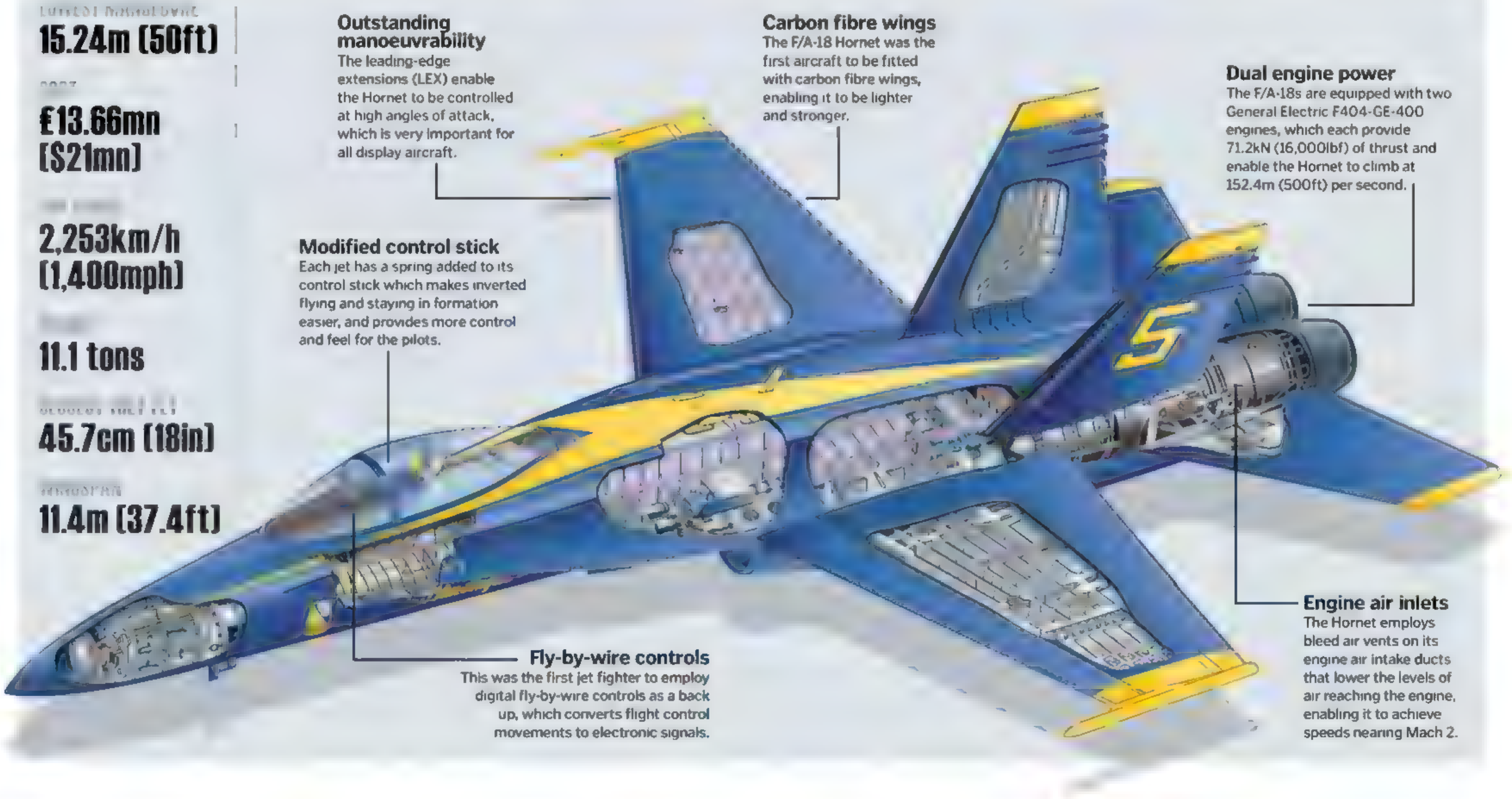
€13.66mn ($21mn)

2,253km/h (1,400mph)

11.1 tons

45.7cm (18in)

11.4m (37.4ft)



Outstanding manoeuvrability
The leading-edge extensions (LEX) enable the Hornet to be controlled at high angles of attack, which is very important for all display aircraft.

Carbon fibre wings
The F/A-18 Hornet was the first aircraft to be fitted with carbon fibre wings, enabling it to be lighter and stronger.

Dual engine power
The F/A-18s are equipped with two General Electric F404-GE-400 engines, which each provide 71.2kN (16,000lbf) of thrust and enable the Hornet to climb at 152.4m (500ft) per second.

Modified control stick
Each jet has a spring added to its control stick which makes inverted flying and staying in formation easier, and provides more control and feel for the pilots.

Fly-by-wire controls
This was the first jet fighter to employ digital fly-by-wire controls as a back up, which converts flight control movements to electronic signals.

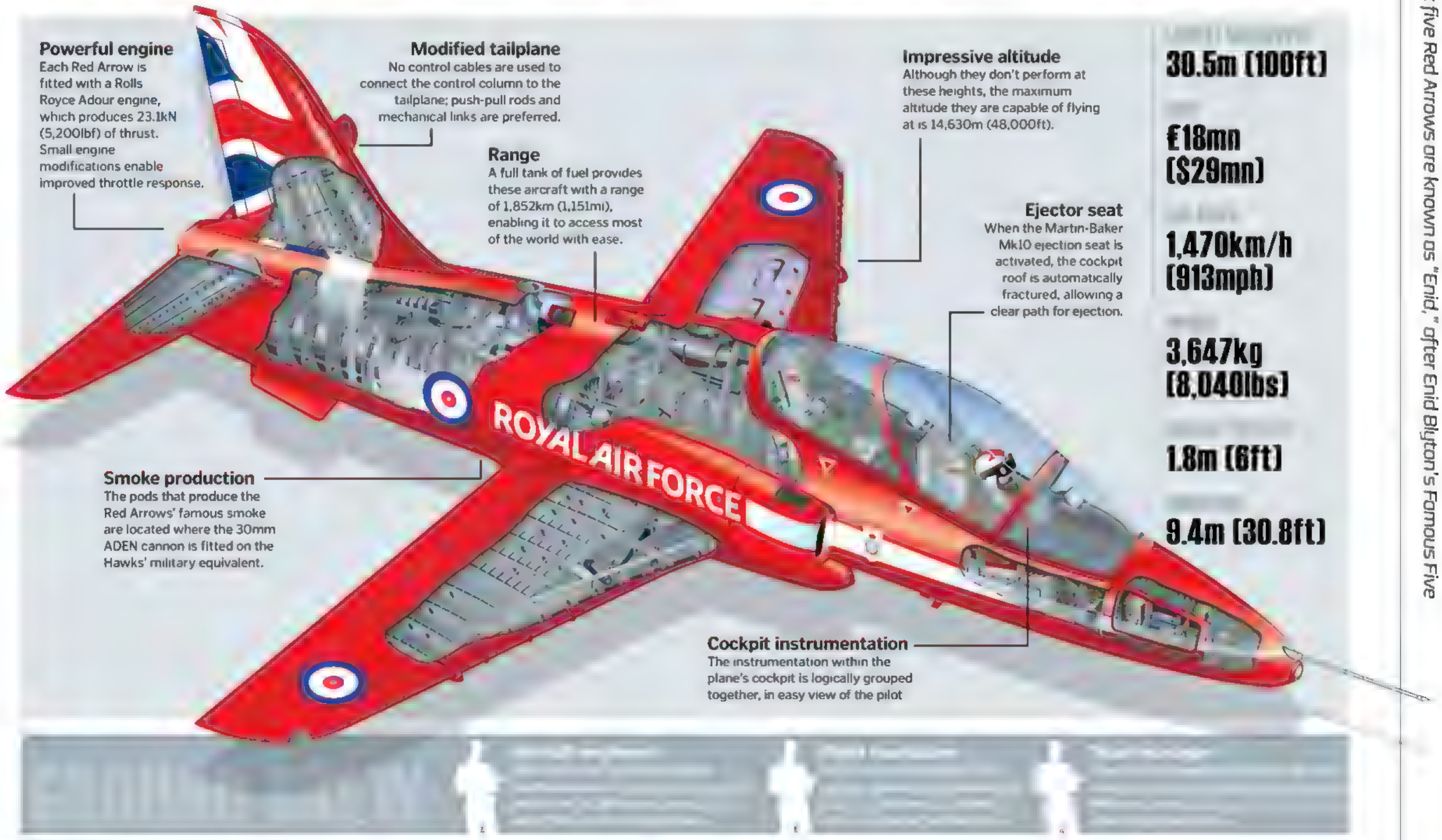
Engine air inlets
The Hornet employs bleed air vents on its engine air intake ducts that lower the levels of air reaching the engine, enabling it to achieve speeds nearing Mach 2.

Red Arrow: Hawk T1

Why the Hawk is still the best choice for displays

The Hawk T1 has been used by the Red Arrows since 1979 and Red 2 pilot Flt Lt Mike Bowden tells us why: "The Hawk is used by the military to train their pilots and the Red Arrows. Hawk is ultimately the same aircraft bar a few modifications," he says. "Although it is somewhat dated, the Hawk is absolutely perfect for what we do. It handles well, especially well in formation, and doesn't have any fancy gadgetry that could go wrong and cause unnecessary problems, which is very important considering how many shows we perform and the precision flying we need to execute."

The Hawk was designed to be easily fixed with the majority of its physical parts interchangeable for convenience – ideal for the Red Arrows who often perform on consecutive days. Maintenance is performed under very strict controls and all procedures are thoroughly supervised and checked to ensure the jets are safe to fly. In addition, the Hawk has backup systems that can be used if the primary system fails.



Powerful engine
Each Red Arrow is fitted with a Rolls Royce Adour engine, which produces 23.1kN (5,200lbf) of thrust. Small engine modifications enable improved throttle response.

Modified tailplane
No control cables are used to connect the control column to the tailplane; push-pull rods and mechanical links are preferred.

Range
A full tank of fuel provides these aircraft with a range of 1,852km (1,151mi), enabling it to access most of the world with ease.

Impressive altitude
Although they don't perform at these heights, the maximum altitude they are capable of flying at is 14,630m (48,000ft).

Ejector seat
When the Martin-Baker Mk10 ejection seat is activated, the cockpit roof is automatically fractured, allowing a clear path for ejection.

Smoke production
The pods that produce the Red Arrows' famous smoke are located where the 30mm ADEN cannon is fitted on the Hawks' military equivalent.

Cockpit instrumentation
The instrumentation within the plane's cockpit is logically grouped together, in easy view of the pilot

30.5m (100ft)

€18mn ($29mn)

1,470km/h (913mph)

3,647kg (8,040lbs)

1.8m (6ft)

9.4m (30.8ft)

Images by Ian Moore

The front five Red Arrows are known as "Enid," after Enid Blyton's Famous Five

STAYING SAFE IN THE SKY

A numbered [illegible] known to keep [illegible] display pilots in one piece

Flying helmet
Although it primarily functions to protect the pilot's head, the helmet houses the communications equipment as well.

Oxygen mask
The Red Arrow pilots all wear oxygen masks fitted with a microphone, but their Blue Angel counterparts do not, as they typically don't fly above 4,572m (15,000ft).

Display flying suit
The Red Arrows and the Blue Angels have their own display suits accordingly coloured to suit their name. These are not worn during training.

Life preserver
The life preserver is equipped with vital survival aids, such as a locator beacon and mini flares.

Personal equipment connector
Red Arrow pilots use this to connect to their aircraft. It provides oxygen and also inflates their 'g' trousers.

Anti-g trousers
Unlike the Blue Angels, the Red Arrows wear anti-g trousers to prevent blood from rushing to their legs during manoeuvres involving strong g-forces.

The Blue Angels are famous for their yellow flight helmet but do not wear an oxygen mask during performances

Combating g-forces

We measure gravity in terms of how much acceleration a force applies to an object. During some of their daring manoeuvres, aerobatic pilots will often be exposed to extreme gravitational forces. These forces direct their blood away from the brain towards their feet, causing the heart to stop pumping sufficient blood back to the brain which will eventually cause the pilot to totally blackout.

There are two ways that aerobatic pilots can counteract this problem. Red Arrow pilots wear a g-suit which employs a compressed air and bladder system. This compresses the legs and abdomen, reducing the likelihood of a blackout by reducing the amount of blood able to flow away from the brain.

Blue Angel pilots undergo specific training to enable them to fly without g-suits. This is because it is impossible to wear them when they fly, as they rest their forearms on their legs and use their knees as a fulcrum which the suits could interfere with if worn. Instead, they learn to tense their lower body muscles and exhale sharply (known as the 'hick' manoeuvre), that slows the rate at which the blood flows away from the brain. Blue Angel pilots are mandated to exercise at least six times a week, which keeps them fit and helps their bodies cope with g-force. On top of this, they train in a centrifuge each year which exposes them to extreme g-force and lets them practice dealing with its effects.

What it takes to be a display pilot

Learn about the rigorous interview and training that future pilots have to face

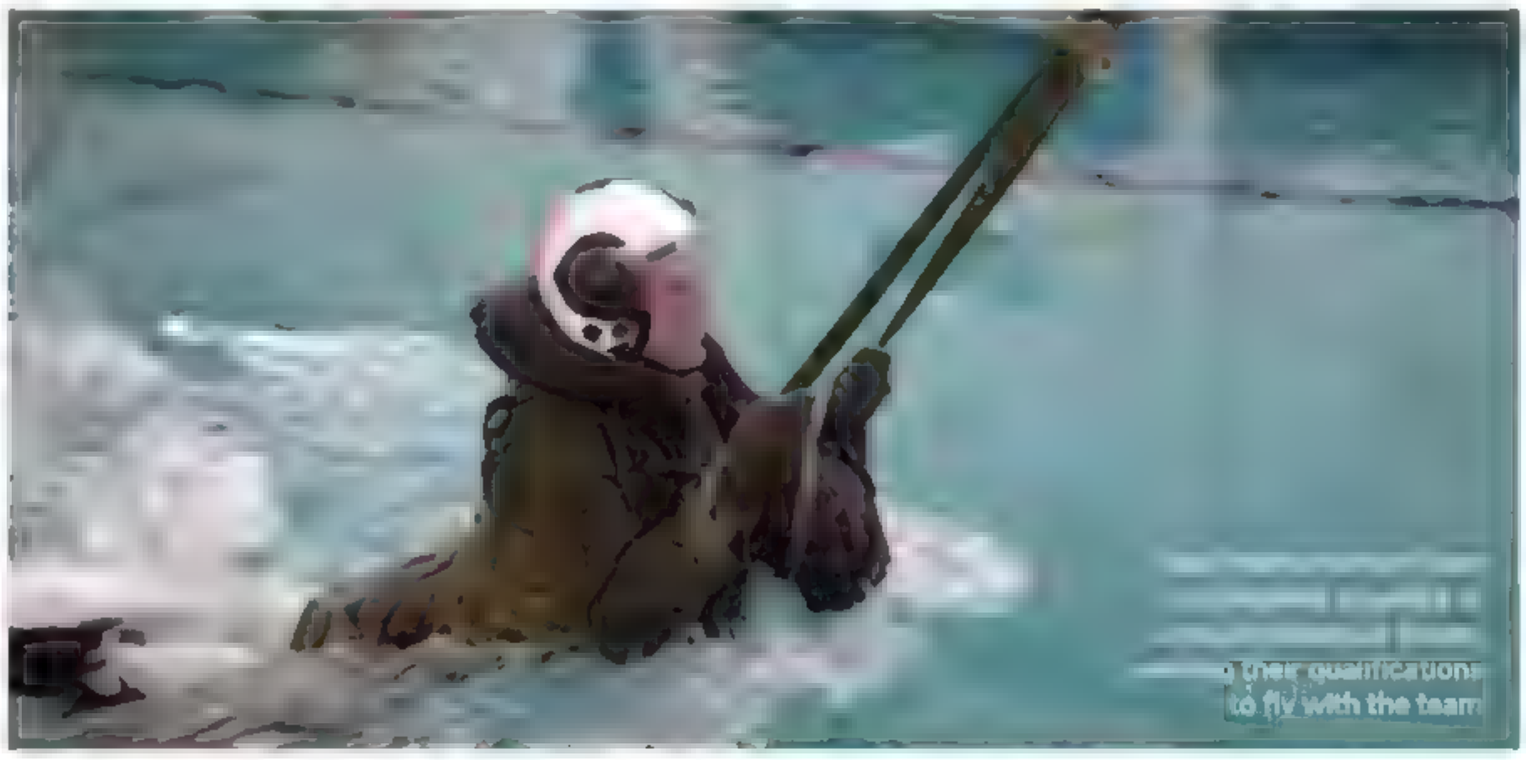
As you would expect, the interview process for selecting a new member of a display team is incredibly thorough. In the case of the Blue Angels, there has to be a completely unanimous (16-0) vote in favour of a candidate in order for them to join.

The Red Arrows will shortlist nine potential pilots via a pre-selection board, who are then invited for the seven-day interview. During this time, the candidates will undertake a flying test, meet the current team, accompany a Red Arrow pilot during a display practice and be formally interviewed. Once this has been completed, the current team will meet to decide which applicants have been successful.

Flight lieutenant Mike Bowden, who pilots Red 2, explains how first-timers learn to fly in unison: "When you fly in formation on the front line, you wait for the aircraft around you to move and copy what they do," he says. "If we were to do this in the Red Arrows it would make the overall formation look very broken, which is why we learn to follow voice commands from the 'Boss' Team Leader). We aim to perfect formation flying before moving onto the complex manoeuvres."

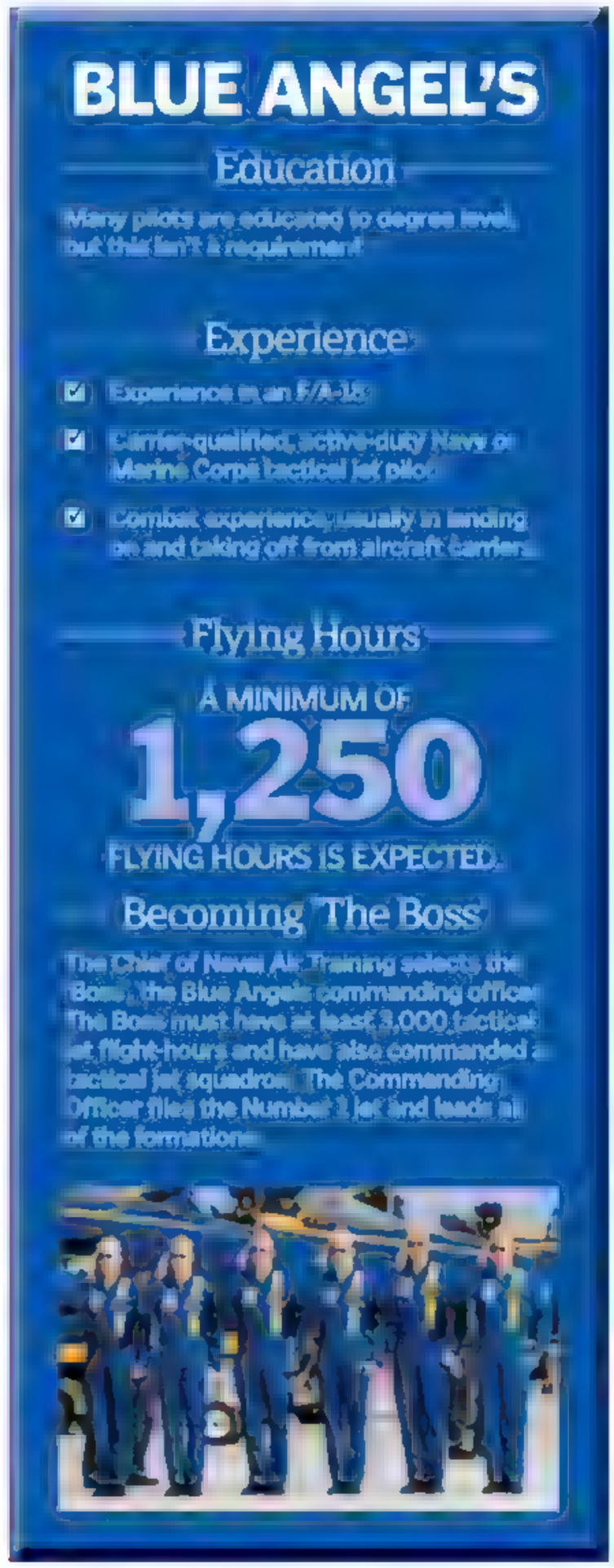
After meeting the initial criteria, Blue Angel applicants, or 'rushees' as they're fondly referred to, shadow the current pilots for numerous displays, typically from April until June. They watch everything the existing team do, attend team briefs and go to social engagements. Candidates are then whittled down, with the remaining potential pilots put forward for a daunting one versus 16 interview, where all current Blue Angel pilots and officers ask the candidate a question.

After this, the current team sits down and decides which candidates will be joining the following year's team. We spoke to LCDR Mark Tedrow, the lead solo pilot for the Blue Angels, who revealed how they train: "The Blue Angels are so unique and the flying we do is very different to anything you do in the military – it really does feel like learning to fly all over again," he says. "Between the end of one season and the start of the next, we aim to accumulate 120 training flights. This means that we are usually flying 15 times per week, which is a fairly gruelling schedule, but that means we can perform our manoeuvres practically from muscle memory."



The experience you'll need to qualify

With only three spots available each year, gaining a place in a display team needs a very specific set of skills



WHY IS THE SKY BLUE?

And 50 other questions about colour

Why is the sky blue?

01 Sunlight is made up of multiple colours, each with a different wavelength. When light travels in a straight line, all of these wavelengths – or colours – of light are combined, so all we see is white light. However, if something such as a mirror, prism or a gas or water molecule gets in the way, then the wavelengths are reflected, bent or scattered into their individual colours. The longer wavelengths are red in colour, but as they get shorter they change to orange then yellow then green and finally blue and violet, which have the shortest wavelengths of all the colours we can see. The way these wavelengths of light interact with the Earth's atmosphere is what makes the sky appear blue.

The scattering of light

How our atmosphere turns the sky blue

Sunset
When the Sun is lower in the sky, the light has to travel further through the atmosphere.

Red sky
More of the short, blue wavelengths are scattered away, leaving only the long red wavelengths to reach our eyes.

Red travels straight
The longer wavelengths of light towards the red end of the spectrum pass through the atmosphere unaffected.

Yellow Sun
When the combination of longer wavelengths reaches your eyes it makes the Sun appear white or yellow.

Gas molecules
When sunlight enters Earth's atmosphere, it collides with gas molecules of nitrogen and oxygen.

Blue scatters
The gas molecules scatter the shorter, blue wavelengths of light in all directions, making the sky appear blue.

No purple sky

White horizon
By the time the light reaches the horizon it has been scattered so many times, the colours combine and appear white again.

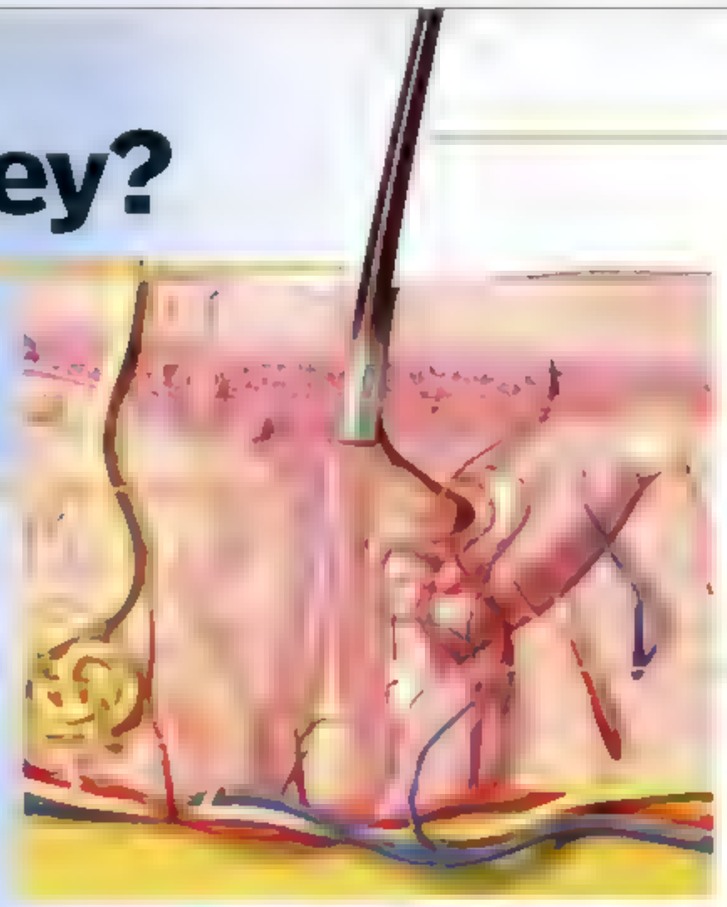
Why does hair turn grey?

02 Going grey is an unavoidable part of the ageing process but contrary to popular belief, it doesn't actually cause your existing hair to turn a different colour. The cells that give your hair its natural colour (melanocytes) eventually die, and once this happens any new growth will appear grey or white. When and how quickly this happens is mainly down to your genes. Just as they decide what your natural hair colour will be, they also determine when you will lose that colour. Therefore, you should typically go grey at around the same age that your parents or grandparents did.

White hair
Eventually melanocytes stop producing melanin completely, leaving the hair to go back to its natural colour, white.

Going grey
When the melanocytes become less active, less melanin is produced, so any new hairs grow lighter, appearing grey.

Hair producing cells
The melanocytes pass melanin on to cells called keratinocytes that produce keratin, the main component of hair.



Natural colour
Keratin is naturally colourless, but the two types of melanin blend to give it your specific shade of hair colour.

Hair shades
There are two main types of melanin. Eumelanin is dark brown or black, and pheomelanin is reddish yellow colour.

Pigment producing cells
Cells called melanocytes can be found in every hair follicle and produce a colour pigment that is called melanin.

Why is Uluru red?

03 Uluru, also known as Ayres Rock, in Australia is supposed to be grey. However, iron within the rock has reacted with water and oxygen in the air to cause rust to form on its surface, giving it a red-orange hue.

Uluru is a large sandstone rock formation in the middle of the Australian outback

Which came first, the colour orange or the fruit?

05 The fruit. The earliest recorded use of the word was in the 1300s to describe the fruit. It wasn't used as a colour name until 200 years later.

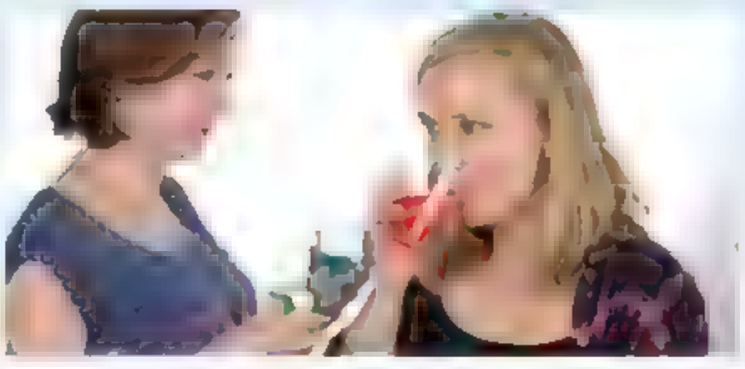
04 Does the colour of food affect the taste?

Find out with some help from your friends and family

1 Pour the drinks
Pour your colourless soda drink into each of the four clear glasses.

2 Add some colour
Add a different food colouring to three of the glasses, leaving the fourth as it is, and stir the drinks.

3 Do a taste test
Without telling them they are all the same drink, get your friends to try each one and ask them to describe the taste.

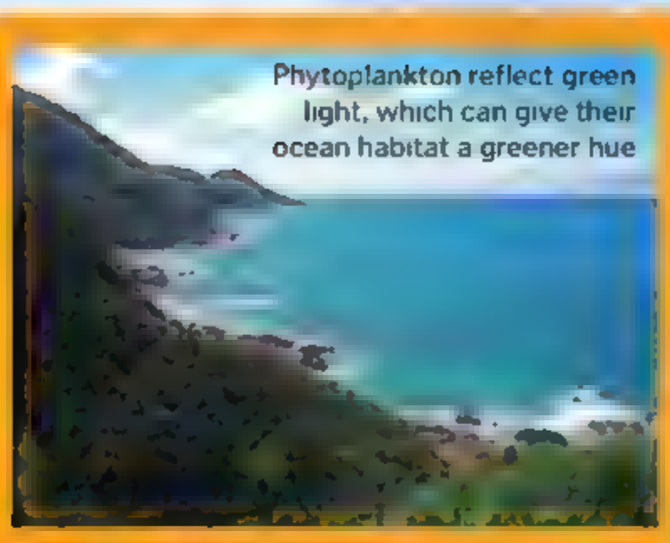


What you'll need
Four clear cups; colourless soda drink; red, blue and green food colouring; friends or family members to take the test

What you'll learn
Even though all of the drinks really taste the same, some of your test subjects may think they have different flavours. This is because when we look at the colour of a drink, our brain will recall memories of how a drink of a similar colour has tasted. It will then predict how it will taste before we actually taste it, influencing our perception of the flavour.

How do butterflies get their colours?

06 The unchanging colours of a butterfly come from coloured pigments in its wings, but many butterflies also seem to shimmer and change colour as they move. They can do this thanks to the structure of their wings. Light hitting microscopic ridges in their wing scales from different angles reflects back different wavelengths (and therefore colours) of light, altering the shades you see.



Phytoplankton reflect green light, which can give their ocean habitat a greener hue

What is colour blindness?

When a person is colour blind it doesn't usually mean they can't see any colour at all. Although there are some very rare cases of black and white vision (called monochromacy), the majority of sufferers are unable to differentiate between certain colours. The cause of colour blindness occurs in the retina which contains colour-sensitive cone cells. Colour blindness occurs when one or more types of these cone cells are faulty or simply not present. The most common form of the condition is red-green colour blindness, which occurs when the red or green sensing cone cells are faulty. This means sufferers can't see red or green properly and also mix up colours containing these shades.

How colour vision works

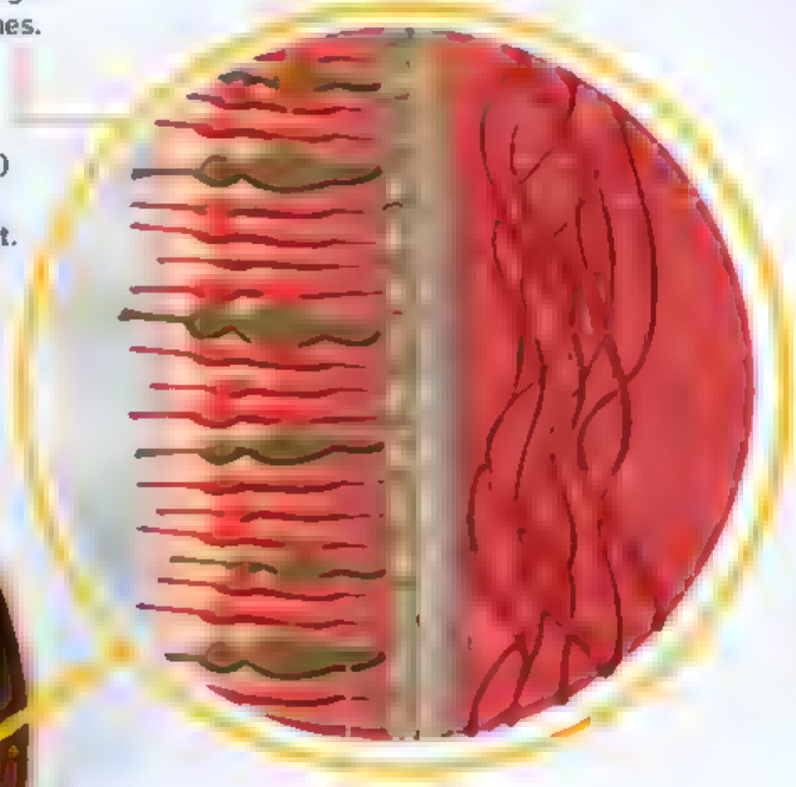
Rods and cones help your brain identify colours

Photoreceptors
The retina contains two types of light-sensitive cells called rods and cones.

Retina
When light enters your eye it eventually reaches the retina, the area at the back that detects light.

Cones
These cells (shown as brown) work in daylight and are sensitive to the colour of light.

Rods
These cells (shown as red) work in low light conditions to help with night vision.



Basic colours
There are three types of cone cell. One senses red light, another senses blue light and another senses green light.

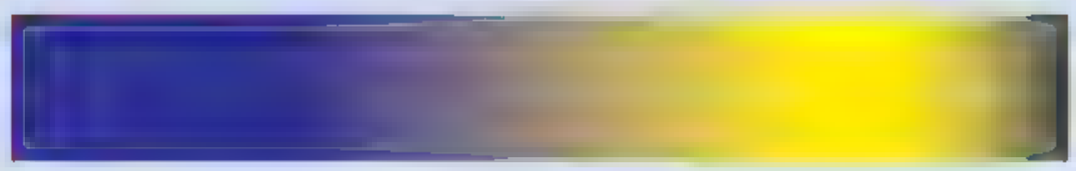
Image processing
When light stimulates the cone cells, they send signals via the optic nerve to the brain that it interprets as colour.

Mixing colours
If an object is purple, the brain will receive signals from the red and blue cone cells to identify this colour.

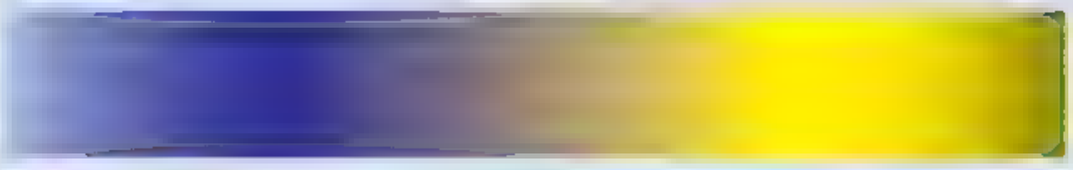
Types of colour blindness

Here's what colour blind people see

Normal vision
When all of your cone cells are working properly you can see the full visible spectrum of colours.



Protanopia
Those with inactive red cone cells are unable to perceive any red light.



Deuteranopia
If your green cone cells are defective, you'll have reduced sensitivity to green light.

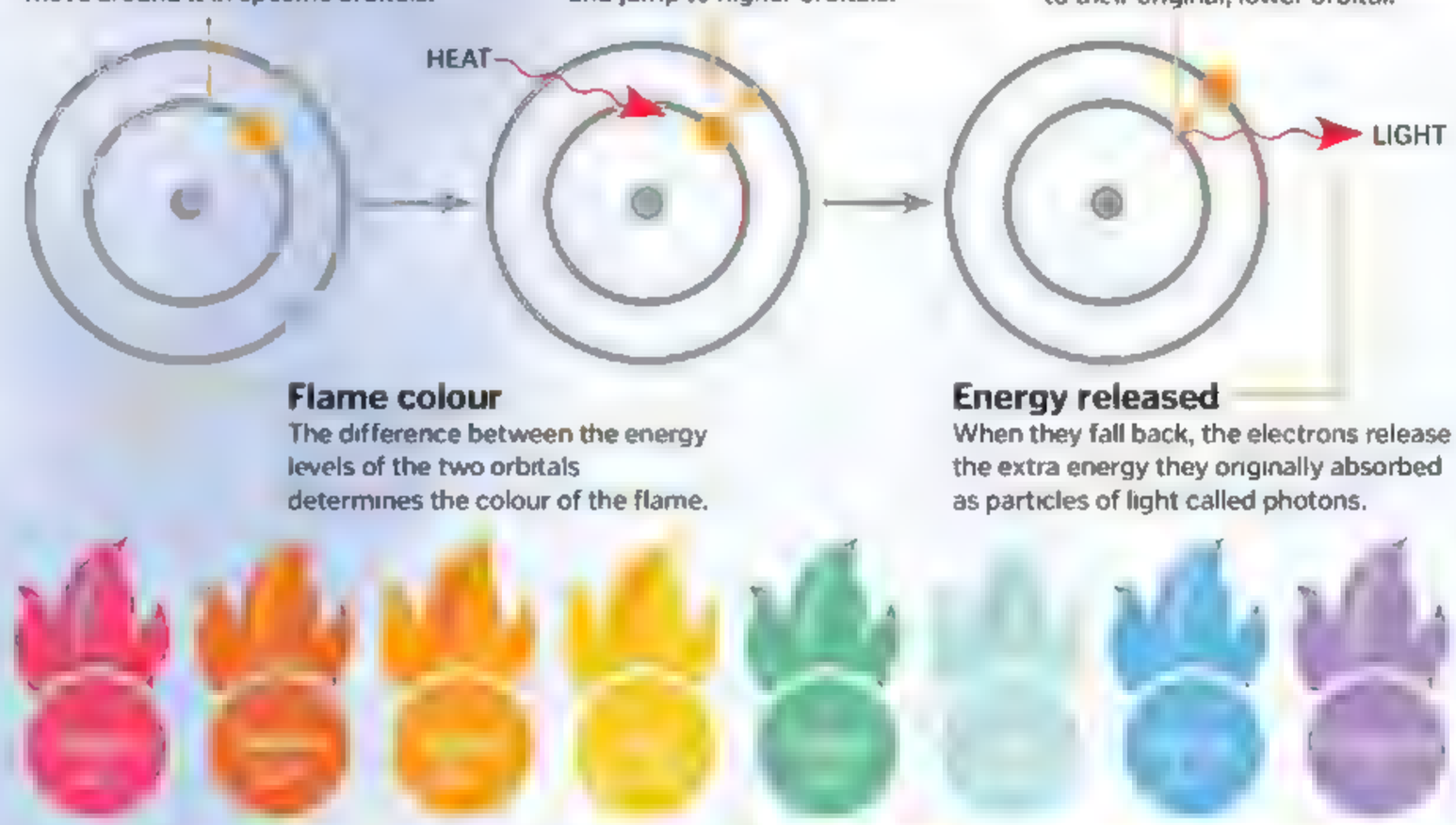
Tritanopia
When your blue cone cells are faulty, you confuse blue with green, and yellow with purple.

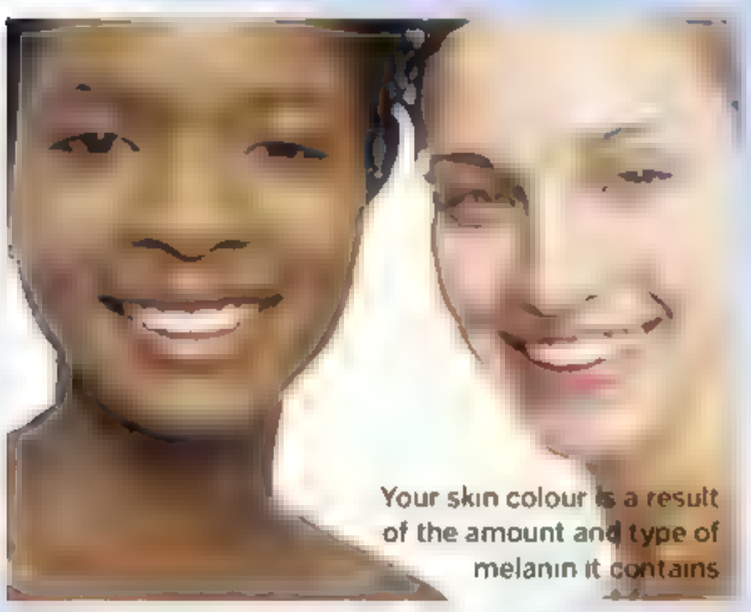
Why are flames different colours?

12 The colour of a flame is a result of the chemicals being heated and the temperature that it is heated to. The light emitted is the energy released by electrons moving within the atoms of the heated substance. In atoms, the electrons orbit the nucleus at specific levels called orbitals. Heat can provide an electron with enough energy to 'jump' up to the next orbital, and when the electron moves back to its original level, the extra energy is released as light. If the electrons travel a small distance they give off low energy, long wavelength light that we perceive as red. If they travel a greater distance, they give off high energy, short wavelength light which is seen as blue. Each individual chemical's atoms have a different arrangement of electrons and orbitals, which inevitably means that they give off their own unique colour when they are heated.

Excitable electrons

How atoms absorb energy and create bright flames




Your skin colour is a result of the amount and type of melanin it contains

Why do people have different coloured skin?

13 Melanocyte cells in the epidermis layer of the skin produce melanin, the pigment that gives it colour. There are two types of melanin; pheomelanin is lighter in colour, whilst eumelanin is darker, and so the colour of your skin depends on the amount of each type produced – a factor decided by your genes. However, the origins of different skin colours are a result of geography. People living in hotter climates evolved with darker skin, because the dark pigment acts like a natural sunscreen to protect against UV rays. Those in less sunny regions developed lighter skin to enable more UV rays to penetrate so their bodies could produce essential vitamin D.

Why are the planets different colours?

14 The colour of a planet is a result of what its surface is made of and how its atmosphere reflects light. Mercury has virtually no atmosphere, so we see the grey colour reflected by its rocky surface. However, Jupiter has an atmosphere containing hydrogen, helium and other elements that reflect shades of white, orange, brown and red.


The composition of each planet's surface and/or atmosphere is what leads to their different colours

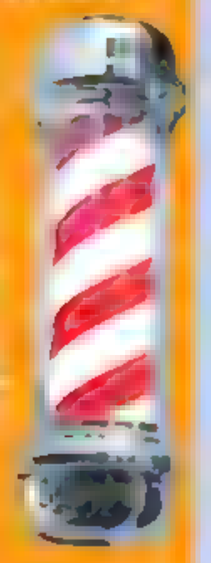

The Statue of Liberty's green coating helps protect it from further corrosion

Why is the Statue of Liberty green?

15 When the Statue of Liberty was first built it was brown, the natural colour of the copper it is made from. However, the copper soon reacted with water and oxygen in the air causing a layer of green copper carbonate to form.

Why are barbershop poles red and white?

16

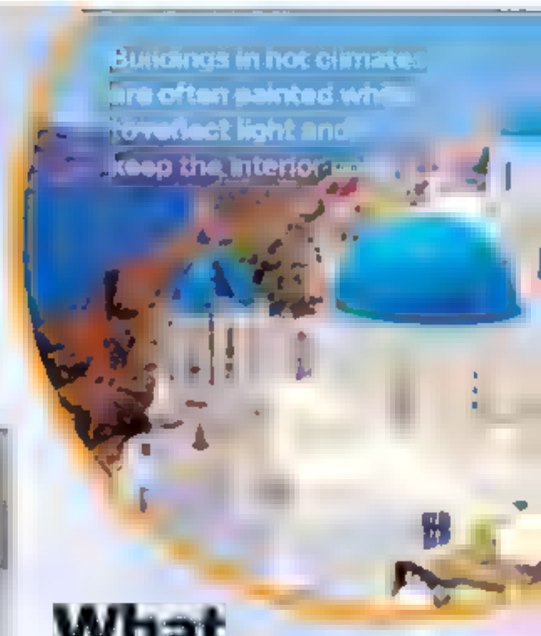


Why does metal change colour when it cools?

17

18 Does colour affect heat absorption?

Test how black and white reflect and absorb heat



What you'll need

Two cardboard boxes
Glue
Black and white paper
Two thermometers

Cover one box

Place a thermometer inside one of the cardboard boxes, then seal it shut and cover it with white paper. Glue the paper tightly in place to ensure that there is no air trapped between the paper and the box, as this could affect the result.

Cover the second box

Now repeat step one using the other box, making sure you seal the other thermometer inside However, this time cover it with black paper instead of white, using glue again to minimise the number of air pockets that could appear.

Leave them outside

Place both boxes outside in an area that receives direct sunlight and leave them there for 30 minutes. When the time is up, open the box and record the temperature on each of the thermometers.

What you'll learn

The temperature inside the white box should be cooler than the temperature inside the black box. This is because the colour white reflects all the wavelengths of visible light and so less of the Sun's radiation gets absorbed and converted into heat. However, black doesn't reflect any wavelengths of light and so absorbs them all, transferring this radiation as heat to the inside of the box.

Can colour affect your mood?

19 Colour can have a big impact on the brain, influencing our mood and emotions. This is why designers are so careful when choosing the colours they use for logos and products. The effects of colours are often a result of the associations we make with them. For example, because red skin typically signals good circulation and fitness, the colour is often associated with dominance. However, colours can also have a physical effect on the human body, as red has been proven to increase heart rate, helping to stimulate attention to detail. On the other hand, blue has been found to have a more calming effect on the body that is good for enhancing creativity. The effects of colours depend greatly on their context though, as some cultures interpret them in very different ways.

Why do some people see colours differently?

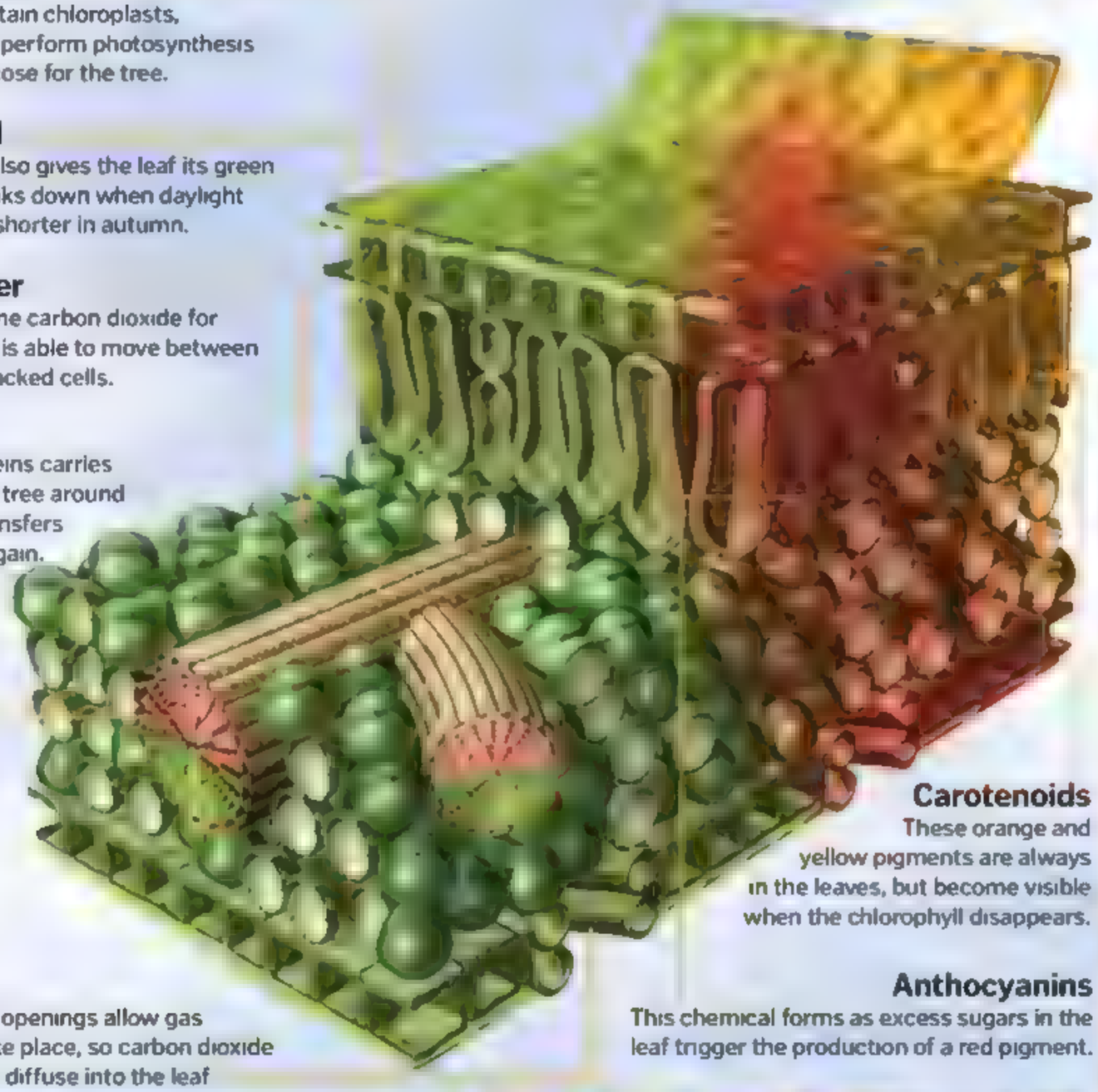
20 The colour our brains perceive an object to be is not always the true colour of that object. One common reason for this is because different sources of light have different colours. For example, incandescent household light bulbs emit a warmer more orange light than the Sun. Therefore, the colour of the light illuminating an object can alter the way its colours look, as white might look a little more orange under warmer light. Our brains are usually good at looking past the colour of the light illuminating an object to determine that objects true colour. However, some people may interpret the colour of the light differently to others, causing their brains to perceive the object as a different hue.

Why do leaves change colour?

21 Every autumn, the leaves on deciduous trees change from a brilliant green to golden yellows, oranges and reds. The green of the leaves comes from chlorophyll, a pigment that absorbs the sunlight required for photosynthesis. The light energy, along with carbon dioxide and water are used to produce oxygen – a waste product – and glucose – a form of sugar that can be used in respiration or converted into other chemicals required for growth or energy storage. The chlorophyll continuously replenishes itself throughout the summer, but in autumn the veins that transport water to the leaf close off, preventing new chlorophyll from forming. This causes yellow and orange pigments that were there all along to become visible and new red pigments to form.

From green to red

The colour changing structure of a leaf



Palisade cells
These cells contain chloroplasts, organelles that perform photosynthesis to produce glucose for the tree.

Chlorophyll
This chemical also gives the leaf its green colour, but breaks down when daylight hours become shorter in autumn.

Spongy layer
Air containing the carbon dioxide for photosynthesis is able to move between these loosely packed cells.

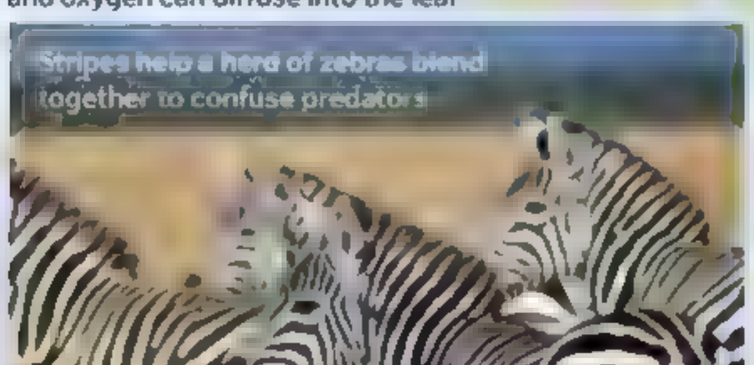
Veins
A network of veins carries water from the tree around the leaf and transfers glucose back again.

Epidermis layer
The transparent surface of the leaf enables sunlight to be absorbed by a layer of palisade cells underneath.

Carotenoids
These orange and yellow pigments are always in the leaves, but become visible when the chlorophyll disappears.

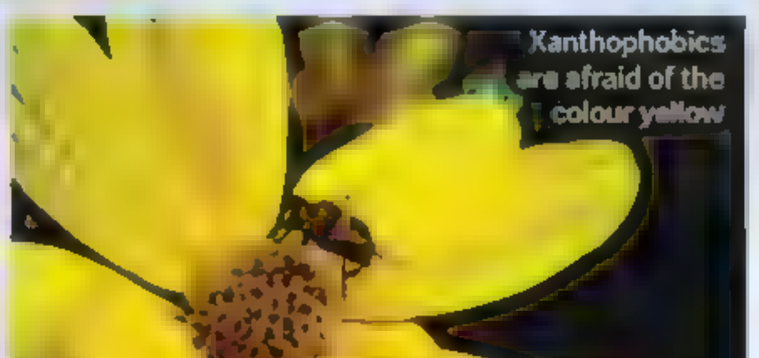
Anthocyanins
This chemical forms as excess sugars in the leaf trigger the production of a red pigment.

Stoma
These pore-like openings allow gas exchange to take place, so carbon dioxide and oxygen can diffuse into the leaf


Stripes help a herd of zebras blend together to confuse predators

What colour are a zebra's stripes?

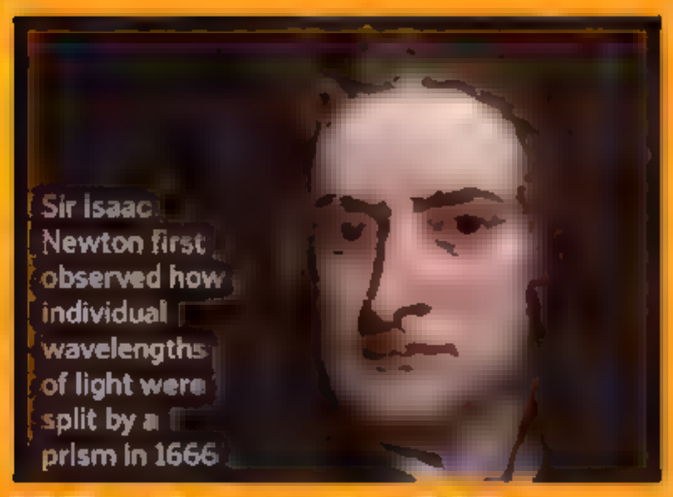
22 Zebras are black with white stripes, not the other way around. Their skin is dark but strips of their fur lack pigmentation to make them white. The stripes serve as effective camouflage.


Xanthophobics are afraid of the colour yellow

Can you have a phobia of colour?

23 The fear of all bright colours is called chromophobia, but some people only fear particular shades and these phobias each have their own names, ie chrysophobia is the fear of orange.

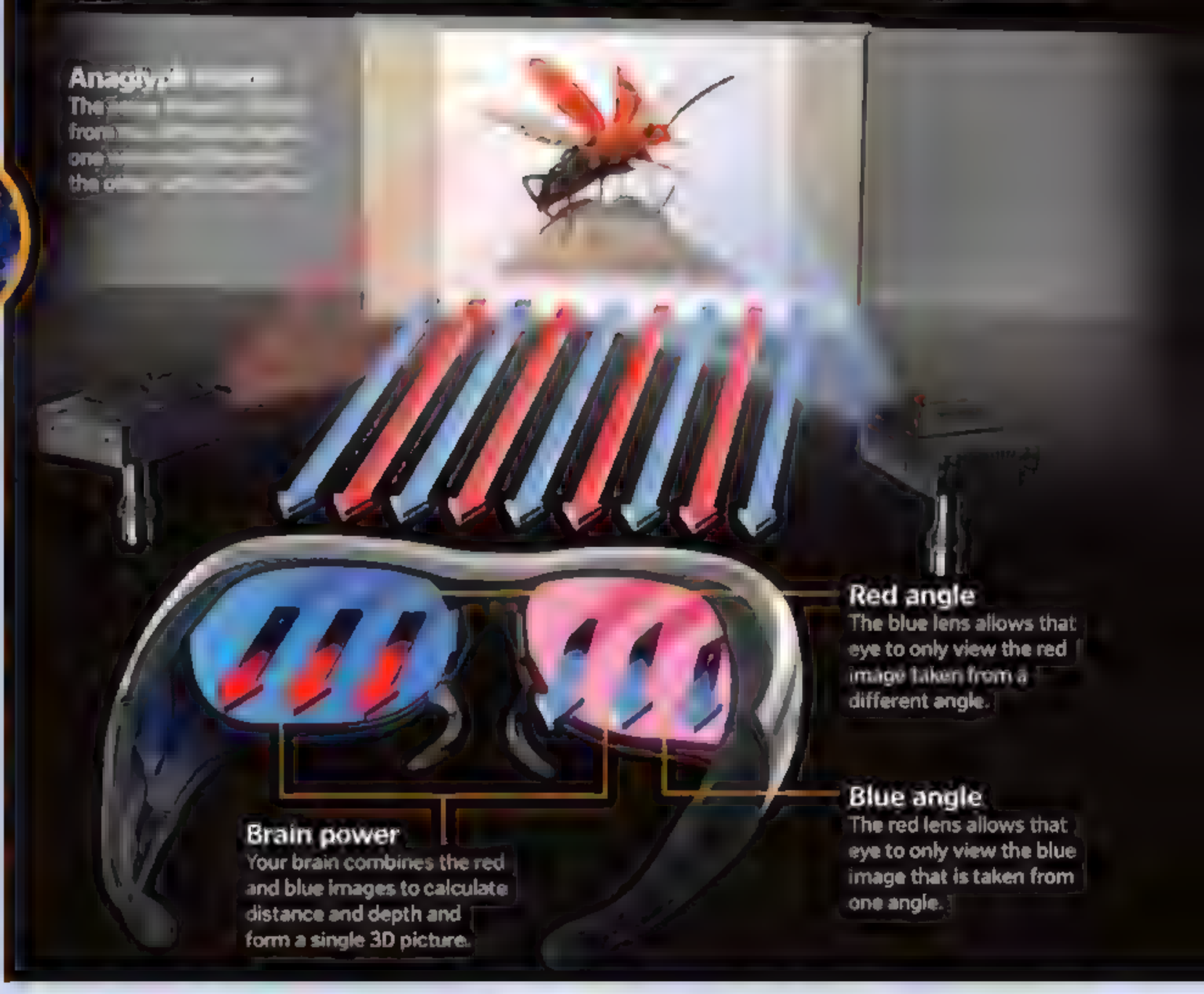

Babies are more sensitive to bold colours and contrasting patterns



Why do 3D glasses have red and blue lenses?

33 They may look a little old fashioned now, but the cardboard 3D glasses with coloured lenses are still used today. As they are so inexpensive to produce, they are often supplied for viewing printed 3D images in magazines and are still needed to watch older 3D movies. They work with images called anaglyph images, which are either taken with different coloured filters or processed later using an editing programme.

When viewed without the glasses, these images look discoloured and blurry, but when you put the glasses on, they trick your brain into seeing a 3D image that jumps off of the page or screen. Modern 3D movies use a different system that needs polarised lenses, as these give a more accurate representation.

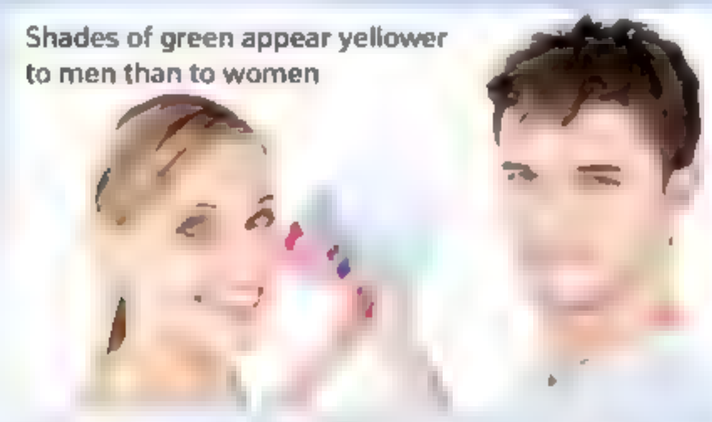


Why are flowers colourful?

34 Flowers are colourful to attract insects which carry pollen from one flower to another so the plant can reproduce. However, certain insects, such as bees, sees flowers very differently. They can see ultraviolet light that is invisible to humans, so they can see the hidden colourful patterns on flower petals that direct them towards the nectar in the centre.

What is albinism?

35 Albinism occurs when the production of melanin, the pigment that colours skin, hair and eyes is reduced, or doesn't exist. It is a genetic condition that can affect both humans and animals, leaving them with pale skin and white hair. It can also cause the eyes to appear red, as light passes through the colourless iris and pupil to reflect off of the blood vessels in the retina at the back of the eyeball.


Shades of green appear yellower to men than to women

Do men and women see colours differently?

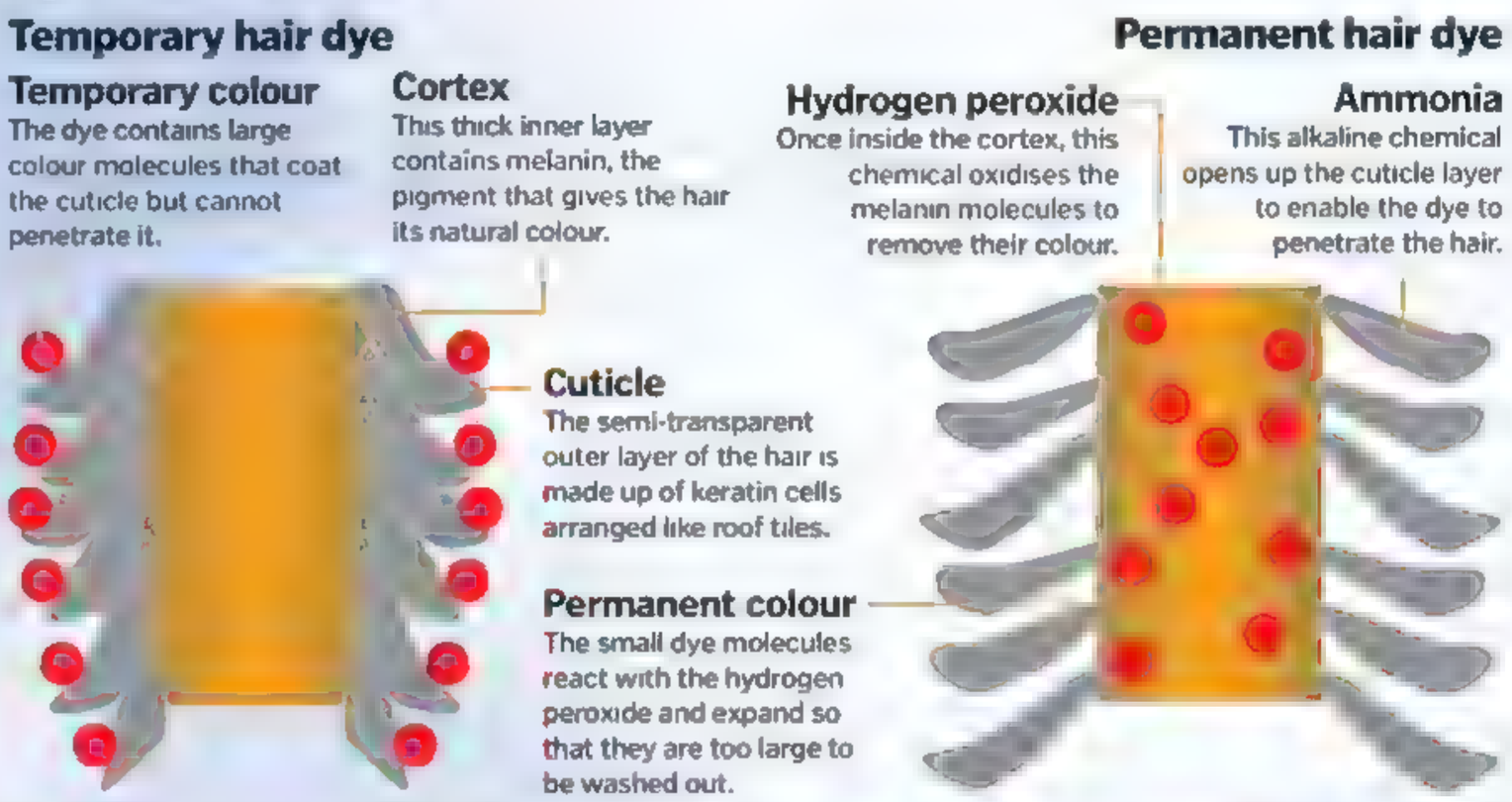
36 A scientific study has found that women are actually better at distinguishing colours than men. A man requires a slightly longer wavelength of light to see the same colour as a woman, so colours will appear slightly warmer to males.

Why is purple often associated with royalty?

37 Purple was [illegible] so expensive that only the rich could afford it. This was because the dye originally used to make purple came from a small mollusc only [illegible] just one gram (0.04 ounces) of dye.

How does hair dye work?

38 Whether you just fancy a change of hair colour, or are determined to cover up grey hairs, hair dyes are a quick and easy way to change your look. There's a range of different products available from temporary to permanent options, each containing different ingredients to produce different effects. Temporary dye doesn't interact with the natural colour pigment of your hair, so it can only darken the colour and lasts for just a few weeks. However, permanent hair dye contains an oxidiser (usually hydrogen peroxide), which works as a bleaching agent to strip your hair of any colour so the dye can replace it. However, as it only affects the colour of your existing hair, any new hair that grows will still have your natural colour.



Which car colour is the safest?

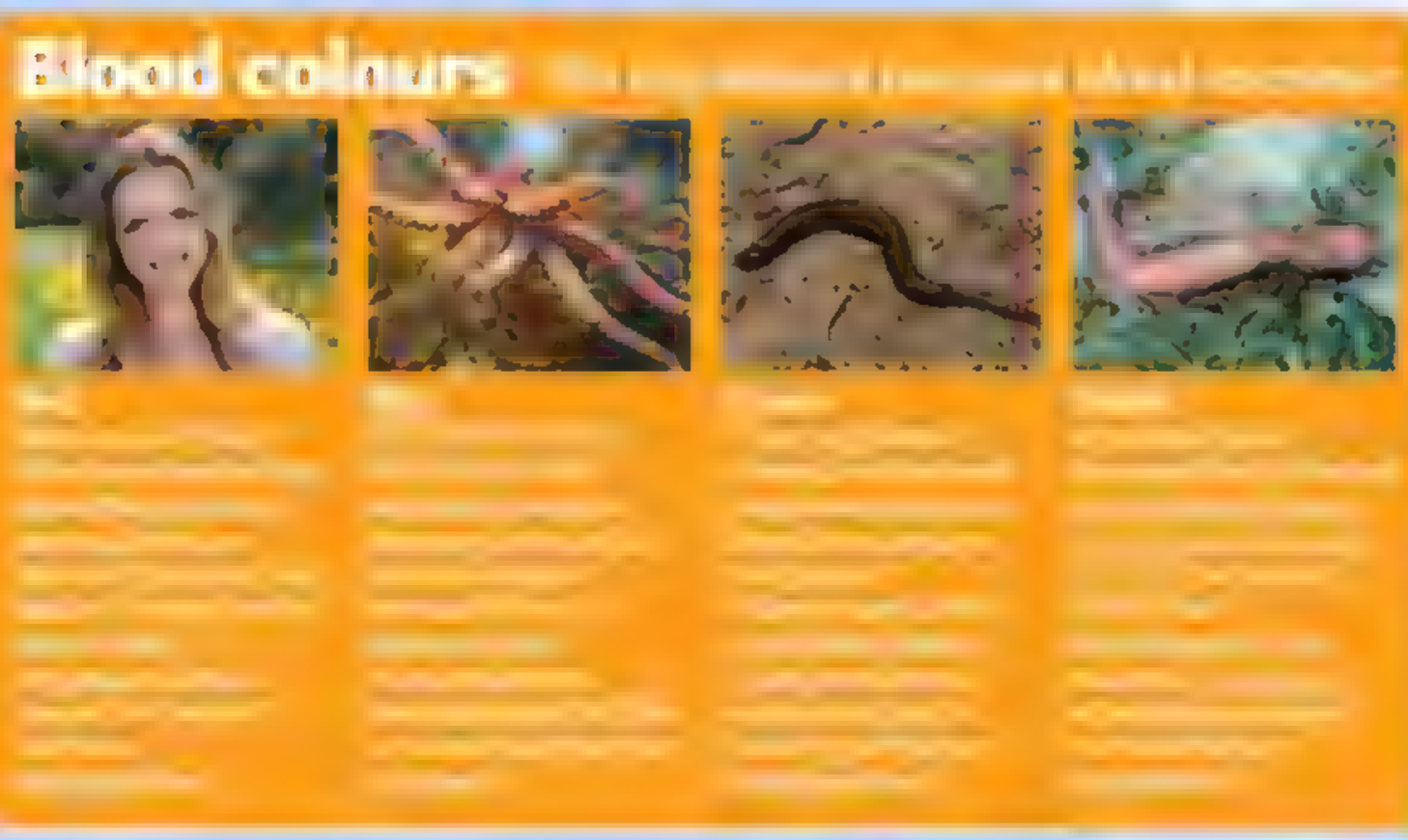
39 Lighter coloured cars are less likely to be involved in a crash because they are easier to see in all road conditions. However, there is some debate as to whether silver or white is the safest.

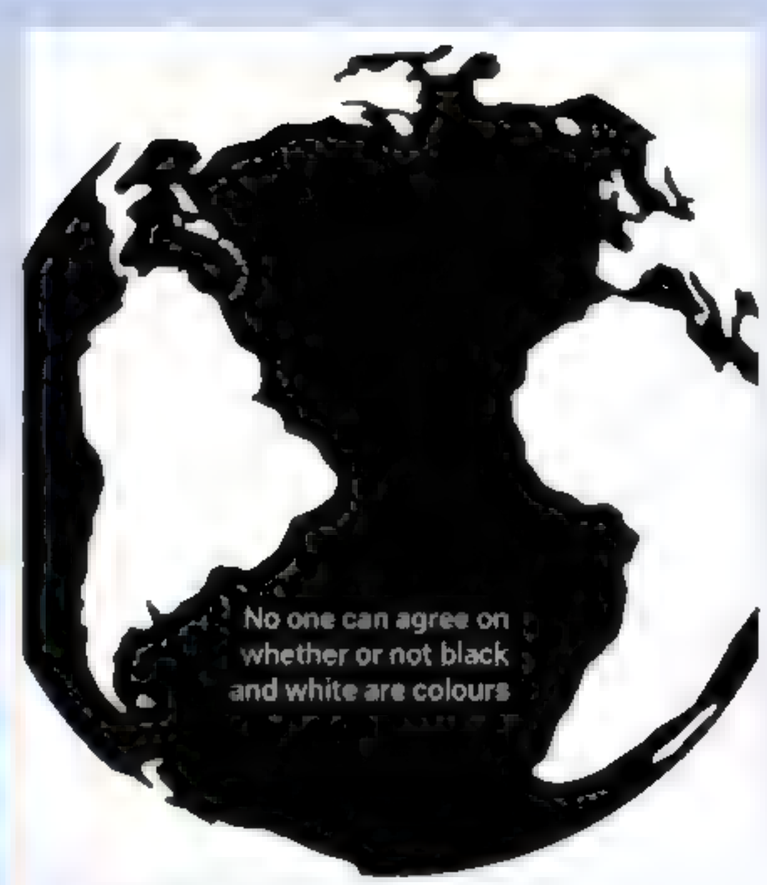
Why are clouds white?

40 Clouds are made up of water droplets. When light hits these droplets they are large enough to scatter all its wavelengths in mostly the same amount, so no particular colour dominates. We see the resulting mixture of all the wavelengths so the cloud appears white. Raincloud often appear darker because they contain more of these water droplets. This means that they scatter more light, causing less of it to transmit through the cloud to reach our eyes.

Is blood always red?

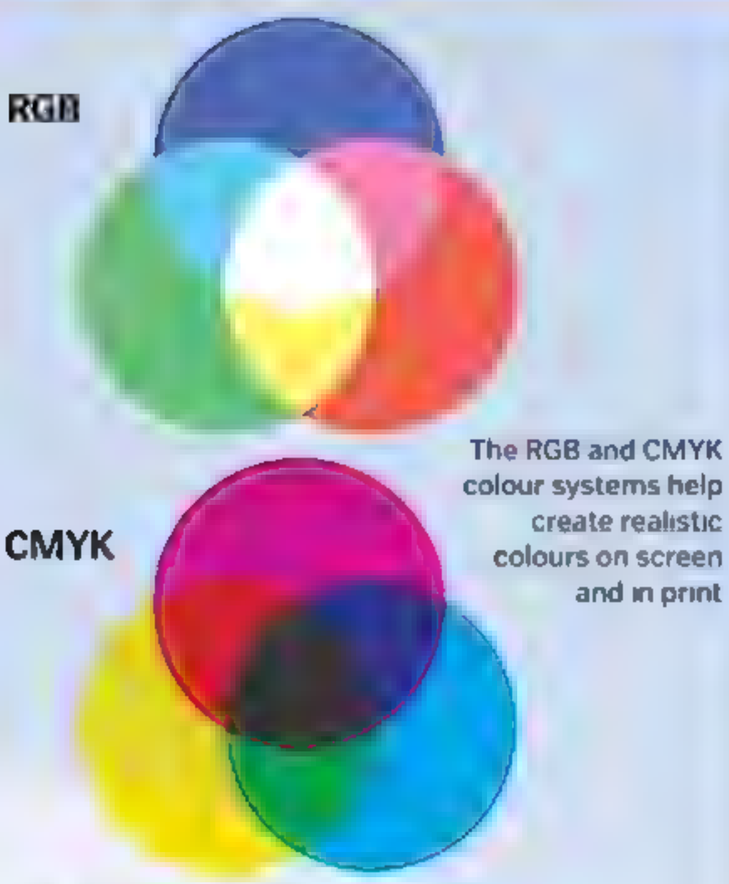
41 When you see blood outside of the human body it is red, but when you look at the blood vessels under your skin they appear blue. Many people to assume that the deoxygenated blood being carried through veins to your heart is actually blue in colour, but this isn't true. The colour of blood does vary slightly depending on the amount of oxygen it contains, but it is always a shade of red. Your veins look blue because of the way light penetrates your skin. Only the blue wavelengths of light are able to travel all the way to your veins and reflect back towards your eyes, so that is the colour that we see. However, some other creatures do actually have different coloured blood.





Are black and white colours?

42 Whether black and white are actually colours is widely debated. In terms of the physics of light, black isn't a colour because it is created by the absence of all wavelengths of light, whereas white is because it is a combination of all wavelengths. However, if you consider the chemistry of colour pigments and molecules, black is a colour because it can be made by combining all three primary colours, whereas white isn't because it is created by the absence of these colours.



The RGB and CMYK colour systems help create realistic colours on screen and in print

What's the difference between RGB and CMYK?

43 RGB stands for red, green and blue, and is the system used to create realistic colours on digital mediums such as televisions and computers. The pixels on the screen are one of these three colours and blend together to create all the colours we see. CMYK stands for cyan, magenta, yellow and key (black) and is used for colour printing. Tiny dots of these colours are printed onto paper and appear as the intended colours to our eyes.

How do chameleons change colour?

44 It's a myth that chameleons change colour to camouflage. The real reason is to communicate their mood to other chameleons. They do this using nanocrystals contained within their skin. When they are calm, the crystals are close together, causing them to reflect only short blue wavelengths of light that mix with the natural yellow pigments in their skin to form green. When they are excited or threatened, the crystals spread further apart, so longer redder wavelengths are reflected instead.

When relaxed a chameleon is naturally green, helping it blend in with its surroundings

What is the most popular colour for national flags?

Red is the most popular colour, appearing on over 75 per cent of national flags, while red, white and blue is the most frequent colour combination. This is thought to be because many flags were inspired by those arising from the American and French revolutions.

Purple is the least popular flag colour, appearing on just over 1% of them

46 Does the colour of light affect plant growth?

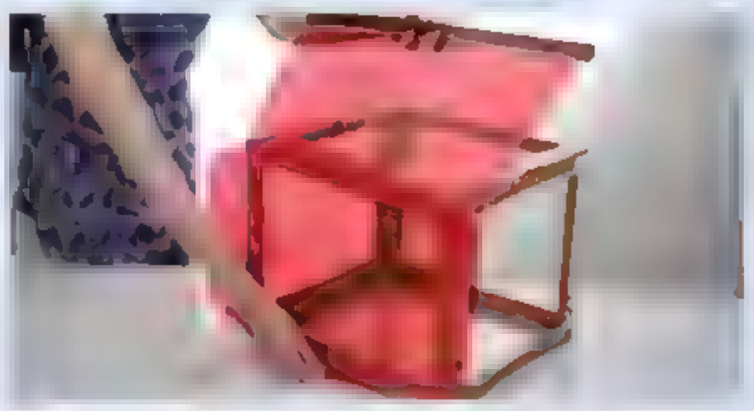
Create your own coloured greenhouses to find out

1 Prepare the greenhouses

Use a pair of scissors or a box cutter to cut a square shaped hole in every side of your three boxes. This will leave you with just the edges and corners of the boxes so you can create cardboard frames.

2 Filter the light

Cover one cardboard frame with red cellophane, another with blue cellophane and another with green cellophane, using tape to secure them in place. Ensure the cellophane does not overlap so that only one layer is covering each side.



3 Plant the seeds

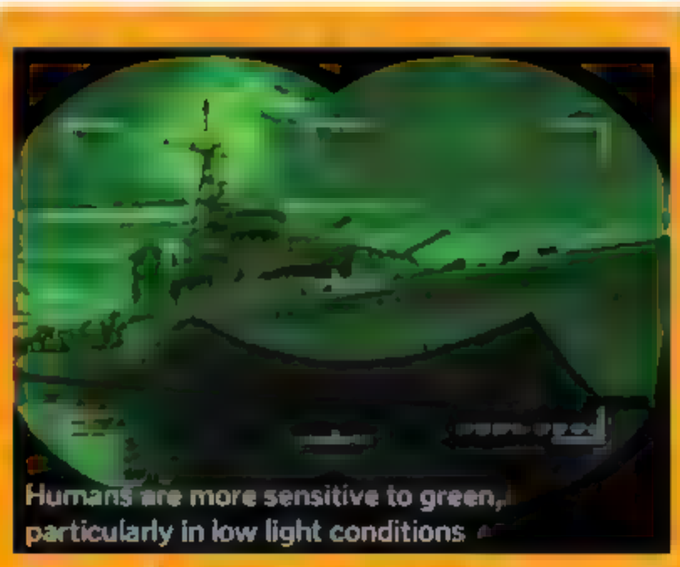
Fill three plant pots with soil and plant your seeds. Place them in an area that gets lots of sunlight and cover them with your greenhouses. Water them at night so they are not exposed to other colours of light.

What you'll need

Three cardboard boxes
Scissors
Red, green and blue cellophane
Tape
Three small plant pots
Soil
Plant seeds

What you'll learn

You should notice that the plants under the red and blue greenhouses grow the most, as blue light is best for leaf growth and red light combined with blue light encourages flower growth. The plant receiving only green light should barely grow at all as it will reflect the light instead of absorbing it. This reflecting of green light by its chlorophyll is what gives the plant its green colour.



Humans are more sensitive to green, particularly in low light conditions

What is tinnitus?

Find out why your ears ring after a concert

Tinnitus is a sound you can hear that isn't caused by an outside source and often manifests as a buzzing, ringing, whistling or humming noise. One of the most common causes of tinnitus is exposure to loud noises, which is why you often experience a ringing in your ears after going to a music concert.

The loud music can temporarily damage the hair cells inside your ear and cause your brain to create phantom sounds that aren't really there. They usually disappear after a while, but prolonged exposure to loud noises can damage the hair cells permanently, resulting in a buzzing that never goes away. There is currently no cure for this type of tinnitus as the hair cells are unable to repair or replace themselves. Therefore, if you're regularly exposed to loud noises, it's important to wear earplugs to protect your delicate ears.

Loud noises are not the only cause of tinnitus, though. Other factors including a build-up of earwax, an ear infection, certain medications, a head injury or even high blood pressure, can also affect the inner workings of your ear and cause phantom sounds.

What's that buzzing?

How your ears and brain interpret real and phantom sounds

Outer ear
Sound waves enter the ear and pass through the ear canal towards the eardrum, causing it to vibrate.

Middle ear
The eardrum vibrates the ossicles (three tiny bones) to amplify the sound. The vibrations are then passed into the cochlea.

Auditory nerve
The bent hairs create an electrical charge, which is carried by the auditory nerve to the brain and interpreted as sound.

Buzzing sound
When it stops receiving electrical signals, the brain spontaneously fires neurons to create phantom sounds.

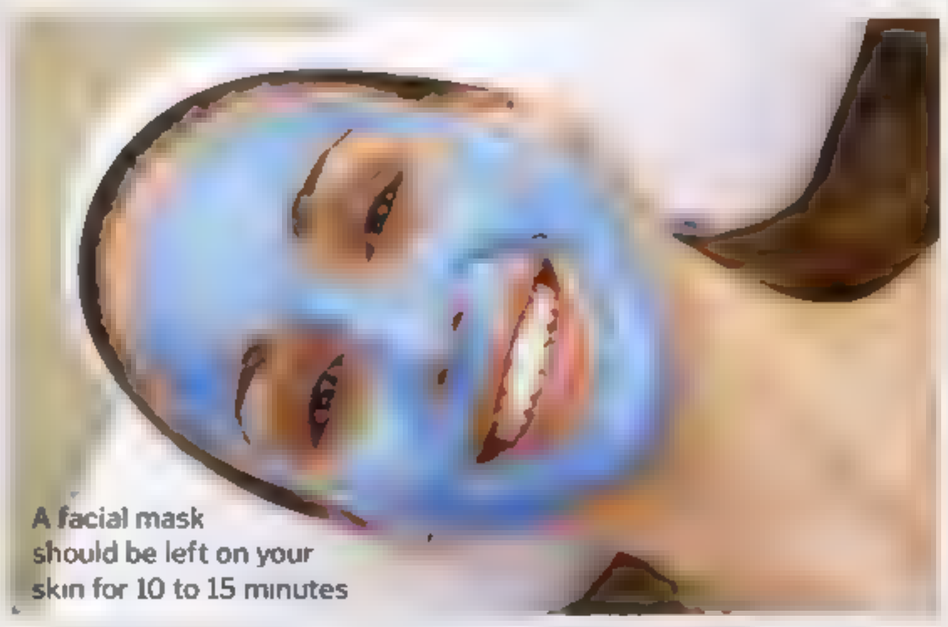
Inner ear
The vibrations cause fluid inside the cochlea to move. The fluid then rushes over and bends hair cells in the cochlea.

Cochlea damage
If the hair cells are damaged, they stop sending electrical signals to the brain.

How do facial masks work?

Discover the beauty benefits of this popular skin treatment

A facial mask is a popular part of any beauty treatment and can help to improve the look and feel of your skin. The ingredients will depend on the particular skin type or condition the mask is intended to treat. Cream-based hydrating facial masks are best for dry skin. They usually contain emollients such as dimethicone, which form a layer of protective film over the skin to attract and trap water molecules beneath it. However, for oily skin types, a mask that will remove moisture is needed. These usually contain clays like kaolin or bentonite, which help to absorb the oil from your pores and draw out any dirt and impurities with it. You can also use self-heating facial masks that work by generating an exothermic reaction, meaning that they give off heat energy. When chemicals such as zeolite or magnesium sulphate in the mask react with water, they release energy as heat. The extra warmth can help loosen or soften any impurities that may be blocking the skin's pores.



A facial mask should be left on your skin for 10 to 15 minutes

THE SCIENCE OF SHOPPING

1 Essentials at the back

Essential items such as bread and milk tend to be at the back of supermarkets, as this forces us to walk through the store and may lead us to buy other items. The smell of freshly made bread from the in-store bakery makes us feel hungry as it activates our salivary glands, increasing the chance of us buying additional items.

2 In-store surveillance

The cameras dotted around supermarkets aren't just for theft detection. They also assess the way people choose certain items to see whether they immediately pick up their choice, or linger and consider the options. This lets supermarkets learn the specific areas in which people are open to new products, as well as where people are consistent.

3 Golden zones

Also known as 'impulse areas', these zones are tactically placed next to checkout queues. They are typically filled with sweets and treats to encourage us to reward ourselves for the task we've just completed. There are often lower shelves as well, to enable children to grab something and ask their parents to buy it for them.

4 Endcaps

We have become accustomed to seeing the short blocks of shelves at the ends of aisles in supermarkets. These tend to include special offers and signage relating to deals. Some stores now put undiscounted items on their endcaps, as this has been found to boost sales, since people are so used to the items in this location being discounted.

5 Larger trolleys

In recent years the average trolley size has increased. The motive for this isn't just to provide us with more space, it's due to the psychological effect this has on us. The larger trolley tricks us into thinking we've got less than we have, encouraging us to keep shopping. A full trolley subconsciously makes us feel that we have finished shopping.

"Supermarkets know that products positioned at eye level or just below sell better "

6 Fresh produce

Fruit and vegetables are at the front of supermarkets for a reason. Seeing the fresh produce as soon as we enter the main store affects us psychologically, making us likely to believe the entire store's food range is fresh and inviting. Some supermarkets even spray their fruit and vegetables with water to give the appearance that it has been freshly picked.

7 Free samples

People are creatures of habit, tending to buy the same things each time they shop. To combat this, supermarkets offer free samples, enabling them to introduce you to new products you wouldn't normally even look at and keep you in store for longer. It may even direct you down a rarely visited aisle.

8 Slow music

Many supermarkets have music playing in their stores, but this is not solely to provide entertainment. Almost all of them play slow music as studies have proven this slows shoppers down, leading to them staying in store for longer and potentially continuing to spend. Classical music encourages shoppers to buy more expensive products, which is why this is played in jewellers.

9 Separate entrance and exit

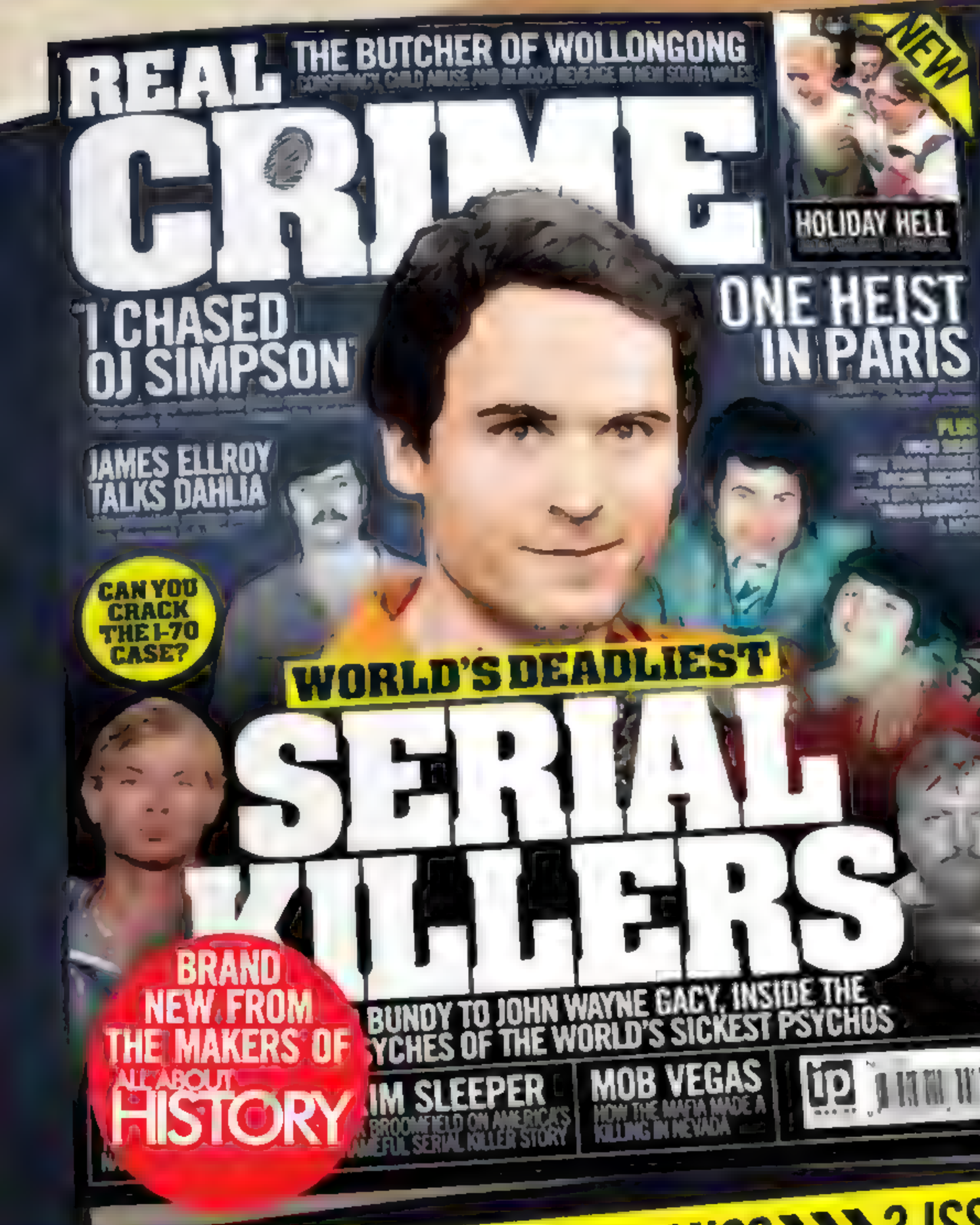
Many supermarkets now have a separate entrance and exit which forces you to walk through the store even if you only popped in to buy a sandwich, or if you don't end up buying anything. Stores are often designed to be shopped counter clockwise, as studies have found that shoppers spend more when they shop in this direction.

10 Eye level is buy level

The position of products on a shelf is incredibly important to supermarkets. They know that products positioned at eye level or just below sell better, which is why you will tend to find branded, high-priced goods in such a position. These days, supermarkets also take advantage of a child's eye level by putting sugary, colourful treats to catch their attention.

Image by Acutee Graphics

THE UNTOLD STORIES BEHIND THE MOST INFAMOUS CRIMES



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Neurotransmitters and your feelings

Are our moods and emotions really just brain chemistry?

Messages are passed from one nerve cell to the next by chemical messengers called neurotransmitters. Each has a slightly different effect and by looking at what happens when neurotransmitter levels change, we are discovering that different combinations play a role in a range of complex emotions.

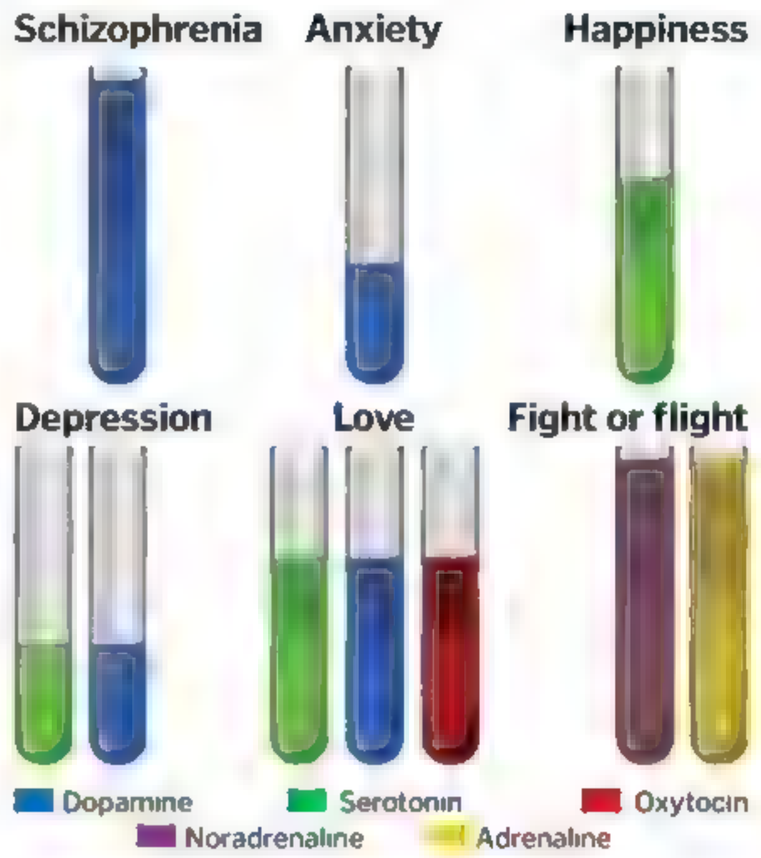
Acetylcholine excites the nerve cells that it touches, triggering more electrical activity. It plays a role in wakefulness, attention, learning and memory, and abnormally low levels are found in the brains of people with dementia caused by Alzheimer's disease.

Dopamine is a chemical that also excites nerve cells. It plays a vital role in the control of movement and posture, and low levels of dopamine underlie the muscle rigidity that exists in Parkinson's disease. Dopamine is also used in the brain's reward circuitry and is one of the chemicals responsible for the good feelings that are normally associated with more addictive behaviour types.

Noradrenaline is similar in structure to the hormone adrenaline and is involved in the 'fight or flight' response. In the brain, it keeps us alert and focussed. In contrast, GABA reduces the activity of the nerves that it interacts with and is thought to reduce feelings of fear or anxiety.

Serotonin is sometimes known as the 'happy hormone' and transmits signals involved in body temperature, sleep, mood and pain. People with depression have been found to have lower serotonin levels than normal, though raising serotonin levels with antidepressant medications does not always help.

There are many more neurotransmitters in the brain and other chemicals like hormones can also influence the behaviour of nerve cells. It is these interactions that are thought to underlie the huge range of human emotions.



Different levels of neurotransmitters have been associated with different mental states

The synapse

Neurotransmitters pass messages from one nerve cell to the next

Receptor
Nerve cells can only respond to a specific neurotransmitter if they have the right corresponding receptors to detect it.

Incoming signal
Neurotransmitter release is only triggered when there is enough electrical activity in the nerve cell.

Neurotransmitters
These chemical messengers travel across the small gap - called the synaptic cleft - and stick to receptors on nearby nerve cells.

New signal
If a neighbouring nerve receives the right chemical messages it will trigger a new electrical signal.

Synapse
Nerve cells communicate by releasing neurotransmitters at specialised junctions called synapses.

Part of a network
Each nerve cell makes thousands of connections to its neighbours and has its own mix of different neurotransmitters and receptors.

Feelings
The combined activity across this complex system is what underpins our thoughts, feelings and emotions.

FAMILY ROBOTS

Meet the robotic helpers who want to work their way into your home and your heart

R2-D2, C-3PO, Rosie Jetson, Johnny 5, Wall-E – popular culture is packed with examples of friendly, sentient robot sidekicks who just want to serve us. Yet despite the human race having sent robots to Mars and beyond, there remains a distinct lack of interactive robots in most of our daily lives. But that might finally be about to change thanks to a few key developments.

Of course, NASA has more money to throw at robotics than us mere mortals. Today, however, the processors, sensors, tiny motors and other components involved are vastly improved and have become much cheaper to produce, thanks largely to the smartphone revolution. Advances in 3D printing and the open source software movement have dragged costs down even further, to the point where emerging social robots are just about in the realm of what is typically seen as affordable – at least for those who can comfortably purchase high-end personal computers or used cars.

A second, arguably even more important, barrier is gradually being overcome too: humanising the technology. It's a fact that, for every adorable R2-D2 in our collective memories, there's a HAL 9000 or a Terminator hell-bent on driving us to dystopia. Stories like *I, Robot* and *The Matrix* have conditioned us to fear a global cybernetic revolt where robots take over our lives and control our every move.

Technology is being developed to enable robots to recognise and respond sensitively to

our emotions. They can perform gestures and expressions that mimic ours – like sagging shoulders or a curious head tilt –making it easier for us to form bonds with machines.

Unlike fabled "robot servants", family robots are intended to engage, delight and enrich our lives. They will help keep us organised with reminders about appointments or medication doses. They will provide genuine companionship and help the elderly live independently for longer by being present and ready to call for help if needed.

"The most important thing for us is to fight loneliness," explained Bruno Maisonnier – founder of Aldebaran Robotics, a French company that produces a number of social robots including Pepper and NAO – in an interview with Yahoo Tech. "If you're angry and losing your humanity, NAO can detect that and do something to help you bring it back. It actually helps humans be more human. That's the part nobody expects."

JIBO

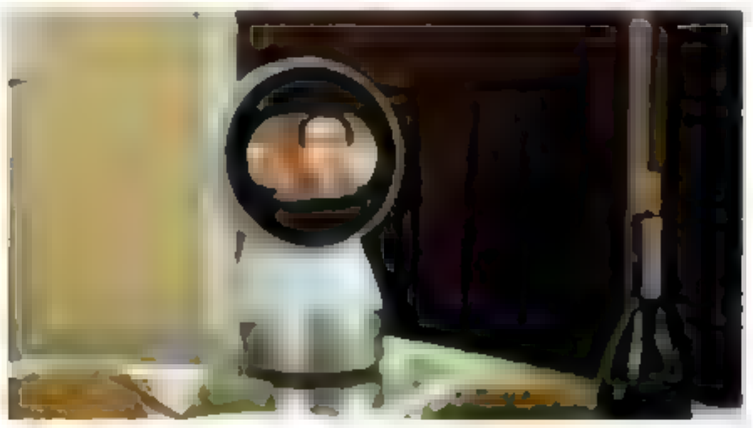
The most adorable pile of electronics ever just wants to be part of your family

JIBO – the runaway crowd-funding success story that reached its goal within four hours – is pegged as "the world's first family robot" and will start shipping in late 2015. Standing stationary at a diminutive 28 centimetres (11 inches) tall, he eschews the traditional humanoid form in favour of something altogether more Pixar flavoured and he simply wants to make your home life run that little bit more smoothly.

Reading his surroundings with a pair of hi-res cameras and 360-degree microphones, JIBO recognises faces and understands natural language. In-built artificial intelligence algorithms help him learn about you, adapt to your life and communicate with you via a naturalistic range of social and emotive movements, screen displays, gestures and sounds.

JIBO's skillset

The many and varied roles of the "world's first family robot"



Communication facilitator

JIBO makes video calls with absent friends and family feel like you're actually in the room together. As the incoming caller, you can direct him to look at a specific person with one tap of your finger and his see-and-track camera will follow them naturally as they move around. When a new person chimes in, JIBO will automatically turn to them.

Photographer

Via his dual hi-res cameras, JIBO can recognise faces, identify individuals and track any activity that is going on around him. Using natural cues like movement and smile detection, for example, he can decide the optimal moment to snap a picture, or will obediently oblige your voice command to take the shot.

Storyteller

Story time with JIBO is just as entertaining as it is with a parent. He regales his playmates with tales embellished with sound effects, animated graphics and expressive physical movements and – using his sensors and special interactive apps – reads and responds to the reactions of his enthralled audience.

Personal assistant

JIBO's camera software recognises each member of your household, enabling him to be a hands-free personal assistant to everyone – delivering reminders and messages at the right time to the right person. When you're busy, he'll search the internet for anything you ask for. He'll even log your takeaway order and place it!

NAO

Say hello to the friendliest social humanoid, created for companionship

NAO is one of the most sophisticated humanoid robots ever built, not to mention one of the cutest. Standing 58 centimetres (23 inches) tall, he is completely programmable, autonomous and interactive. He can walk, dance, sing, hold a conversation and even drive his own miniature robot car! Currently in his fifth incarnation – known as NAO Evolution – he has, in fact, been constantly evolving since he burst on to the scene in 2006.

NAO reads his surroundings via sensors including cameras, microphones, sonar range finders and tactile pads. Today he can recognise familiar people, interpret emotions and even form bonds with those who treat him kindly – roughly mimicking the emotional skills of a one-year-old child.

With a battery life of more than 1.5 hours and an electrically motorised body whose joints give him 25 degrees of freedom, he can navigate his world avoiding obstacles, pick himself up if he falls, and – most importantly – bust out impressive dance moves.

A key feature of NAO's programming is the ability to learn and evolve. Over 500 developers worldwide are engaged in creating applications to run on his NAOqi 2.0 operating system and three gigabytes of memory. Being autonomous, NAO can download new behaviours on his own from an online app store.

Today, NAO is the leading humanoid robot used in research and education worldwide, with more than 5,000 NAO units in over 70 countries, according to his creators Aldebaran Robotics.

NAO's best features

He's a little character with a unique combination of hardware and software

Audiovisual input
NAO is equipped with a pair of cameras and can perform facial and object recognition; a suite of four directional microphones enables him to decipher where sounds originate from and recognise voices.

Vocal synthesiser
Includes text-to-speech capabilities for internet recital; able to communicate in 19 different languages.

Sonar system
NAO judges distances to nearby objects and obstacles using a pair of ultrasonic transmitters (top) and a pair of receivers (bottom) that analyse the time it takes for inaudible sound pulses to bounce back.

Prehensile hands
Enable NAO to grasp and manipulate objects. A trio of capacitive touch sensors in each hand let him know when he has a good grip on something without crushing it.

Feet
Equipped with noise damping soles for a quiet walk and tactile sensors for interacting with objects and obstacles.

NAO's sensitive side

NAO reads human emotions by analysing a set of non-verbal cues. Using data from his cameras, microphones and capacitive touch sensors, he interprets things like how close a person stands, how animated they are, how loud they're being compared to their usual level, what facial expression they're wearing, what gestures they're making and how tactile they are being.

His understanding of emotion has been cultivated using professional actors to help him recognise these non-verbal cues, and he is currently able to accurately detect emotions about 70 per cent of the time. He is programmed with a set of basic rules about what is 'good' or 'bad' for him which help him decide how he ought to respond.

NAO expresses his own emotions via a combination of body gestures and gestures (for example, he will cower and shake if he is afraid), vocalisations and sound effects, and coloured lights in his eyes. Using machine-learning algorithms, he picks up new ways to express himself from the people he interacts with – just like a baby.

NAO uses machine-learning to pick up new ways to express himself

Infrared transceiver
Permits wireless communication with other NAOs or infrared-enabled devices.

Tactile sensor
Communicate with NAO via touch: press once to shut down, or program the sensor as a button that triggers specific actions.

'Brain'
Main CPU, running dedicated NAOqi operating system, enables NAO to interpret and react to data received by his sensors and provides wireless connectivity.

Inertial measurement unit
Includes an accelerometer and a gyro to let NAO know whether he's standing, sitting, or in motion.

Motorised joints
With 25 degrees of freedom and sensors to stabilise his walk and resist small disturbances.

"A key feature of NAO's programming is the ability to learn and evolve"

ROBO-HELPERS

Check out how these robot servants could help make household chores a thing of the past!

Floor cleaning

Automatic vacuum cleaners like iRobot's popular Roomba size up a room and navigate the floor in a random motion as they clean. Roomba's younger sibling, Scooba, can vacuum and wash non-carpeted floors simultaneously, and both devices can be set to clean on a schedule.

Getting up

Good news for those who struggle to get up in the morning: the Clocky robot alarm clock gives users one chance to snooze before it rolls off the bedside table and finds a hiding place – different each day – forcing would-be slumberers to chase it down.

Garden upkeep

Cheating teenagers everywhere out of a little extra pocket money, Robomow works like an outdoor version of the Roomba to keep lawns in pristine condition. It handles all grass types, slopes up to 20 degrees and knows to head for cover as soon as it detects any rain in the air.

Laundry maid

Researchers at UC Berkeley programmed research and innovation robot PR2 to carefully fold fresh laundry back in 2010. Fast-forward four years, and they had it taking dirty laundry to the machine and setting it going too. The catch? Your own PR2 would set you back $400,000 (about £260,000)!

Robo Butlers

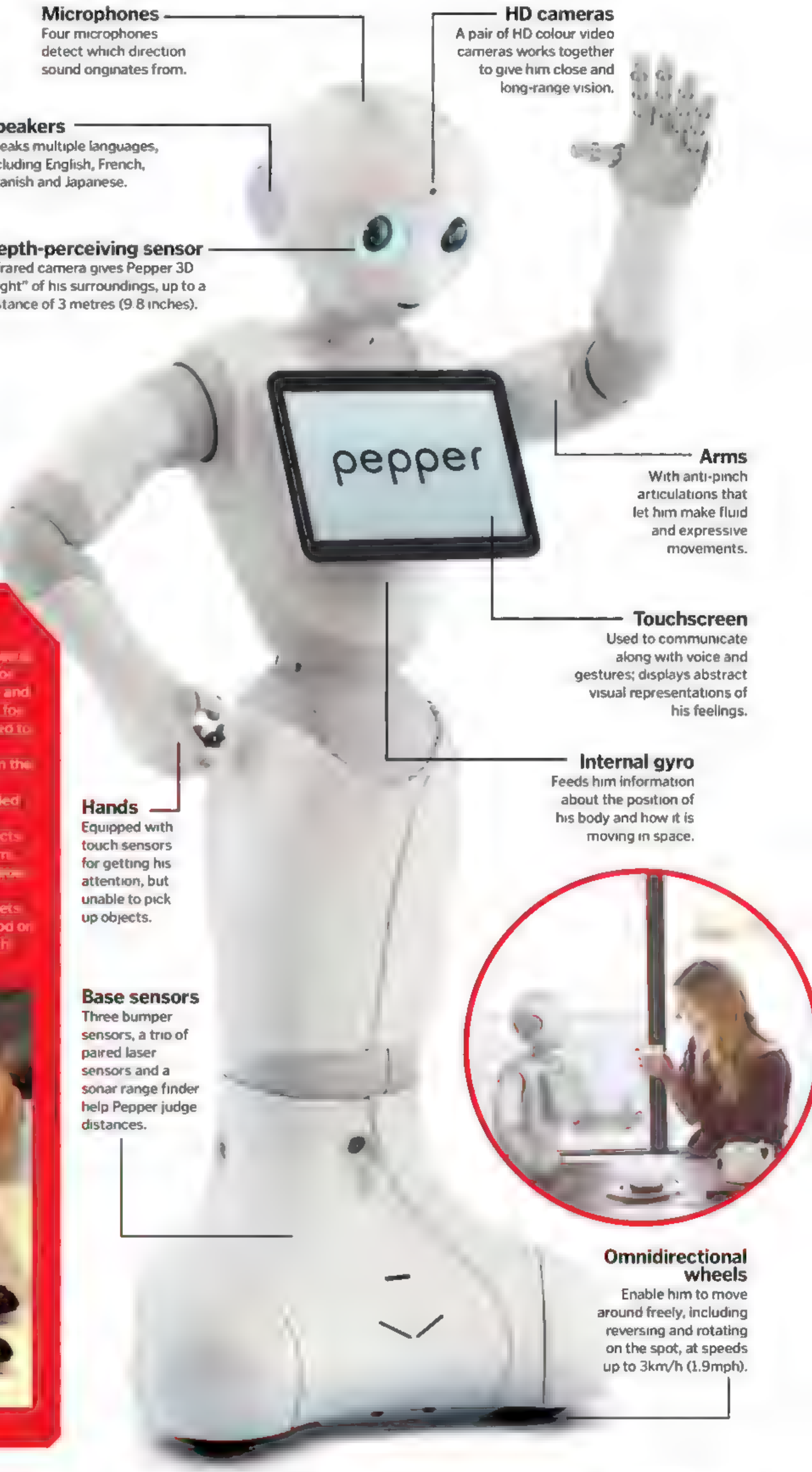
A recent PR stunt from the makers of the Wink home automation app touted a revolutionary (and fake!) Robot Butler but, despite a few early inroads like BrewskiBot – a hefty rolling fridge that is designed to shuttle drinks – robotic butlers have yet to be commercially realised.

PEPPER

The perfect houseguest: a conversationalist who'll adapt to your mood

Pepper is the first autonomous social robot designed to live with humans. Like us, he reads emotions by analysing facial expressions, vocal tone and gestures, and engages people in meaningful mood-appropriate conversations. He exudes 1.2 metres (four feet) "of pure style", rolling around autonomously for up to 14 hours at a time, and even knows when it's time to plug himself in for a recharge.

Pepper learns from his interactions with humans and uploads his generalised findings to the Cloud so that he and other Peppers can evolve as a collective intelligence. This is welcome news because, so far, his jokes are pretty lame! Since June 2014 Peppers have been used in SoftBank Mobile stores in Japan to greet and assist customers. The first 1,000 models were made available to consumers in June this year and sold out in under a minute.



Microphones
Four microphones detect which direction sound originates from.

HD cameras
A pair of HD colour video cameras works together to give him close and long-range vision.

Speakers
Speaks multiple languages, including English, French, Spanish and Japanese.

Depth-perceiving sensor
Infrared camera gives Pepper 3D "sight" of his surroundings, up to a distance of 3 metres (9.8 inches).

Arms
With anti-pinch articulations that let him make fluid and expressive movements.

Touchscreen
Used to communicate along with voice and gestures; displays abstract visual representations of his feelings.

Internal gyro
Feeds him information about the position of his body and how it is moving in space.

Hands
Equipped with touch sensors for getting his attention, but unable to pick up objects.

Base sensors
Three bumper sensors, a trio of paired laser sensors and a sonar range finder help Pepper judge distances.

Omnidirectional wheels
Enable him to move around freely, including reversing and rotating on the spot, at speeds up to 3km/h (1.9mph).

Robotic pets

You may think it's crazy to suggest you could possibly love a robot as much as you love your real-life dog or cat. But for some people, robotic pets offer a chance for connection and companionship that they might otherwise miss out on – for example, older people who are less mobile than they used to be or children with life-threatening allergies.

They've come a long way since the alien-like Furbies in the late 1990s and the multi-functional dogs like Zoomer – which hurls itself around with all the "grace" and unbridled energy of a puppy. Robotic pets have motorised bodies equipped with sensors to detect things like motion, objects and voice commands. Some even have the ability to learn, respond to kindness, develop a unique personality and grow through various life stages, like baby dinosaur Pleo.

Of course, there are the added benefits that robotic pets will never ruin your furniture, don't require expensive food or vet visits and won't demand walkies when it's pouring with rain! All the fun – none of the inconvenience!

All the fun – none of the clean up!

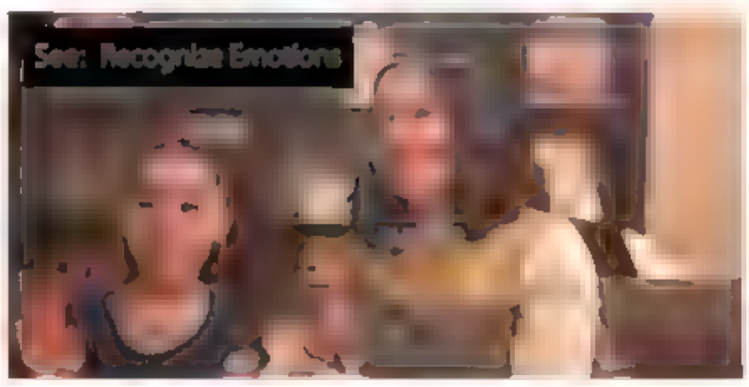
PERSONAL ROBOT

Assistant, security guard, and home automation system all rolled into one

Personal Robot is a smart personal assistant equipped with a heavy dose of artificial intelligence (AI). The 1.2 metre four-foot tall robot consists of a sturdy, wheeled base and a sensor-packed interactive screen carried by a telescopic strut. It navigates its environment autonomously using in-built mapping algorithms to build and memorise the floor plan.

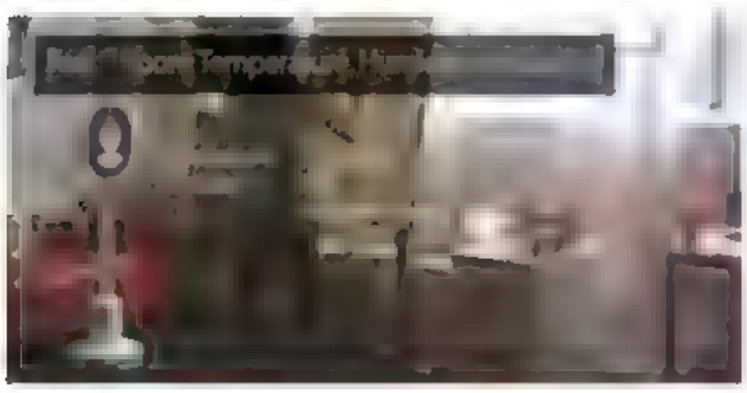
The gender and characteristics of each Personal Robot are customisable and its AI algorithms bring together face, emotion and object recognition, natural language processing and wireless connectivity to allow it to interact seamlessly with its environment and owners. Its creators, New York City start-up RobotBase, expect to start selling the robot by the end of

Personal security guard
Sends you updates and real-time video feeds so you can check on your home and pets while you're gone.



Emotionally intelligent
Recognises human emotions by interpreting facial expressions with artificial intelligence (AI).

Recognises objects
Identifies familiar household objects and wirelessly connects to and controls compatible appliances.

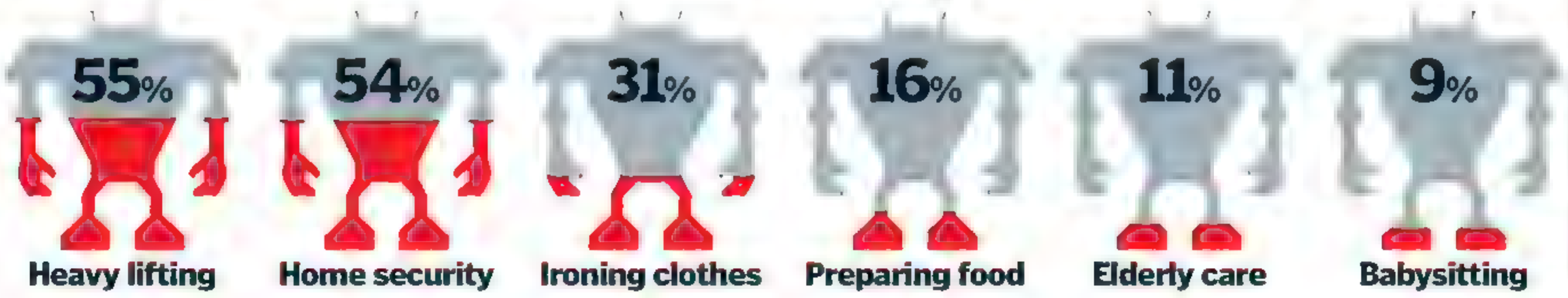


"Feels" the environment
Uses a suite of sensors to monitor variables like temperature, humidity and air quality.

Personal photographer
Recognises good photo opportunities and leaves you free to join your friends in the frame.

Personal assistant
Provides wake-up alarms, appointment reminders, fashion advice, fact-checking and business information.

Survey respondents' likelihood of using a robot for various tasks



How sunglasses protect your eyes

The sight-saving secrets of a summer style staple

Reaching for our sunglasses on a bright, sunny day is second nature; we all know that spending time in the Sun puts us at risk of eye damage and no one enjoys a squinting-induced headache. Perhaps you take them for granted, but there's more to your sunnies than shaded lenses.

Aside from lending mere mortals an air of film star mystique, sunglasses' premier function is to block the Sun's harmful ultraviolet (UV) rays. There are two types of UV rays: UVA (which cause skin cancer and premature ageing) and UVB (responsible for sunburn). Both types have higher frequencies than the visible light our eyes can perceive. They damage our eyes the same way they damage our skin, except that even in the shade reflected rays pose a threat to our eyes.

Sunglass lenses are made from glass, plastic or polycarbonate, with a special UV-absorbing coating. A good pair blocks more than 99 per cent of UV radiation from reaching your eyes. Tints and mirror coatings relieve you from squinting, by absorbing or reflecting intense, dazzling light in the visible part of the spectrum (the light we can actually see).

The highest-grade sunglasses also incorporate a polarising film to combat glare from reflective horizontal surfaces like water, sand and snow. Light waves vibrate just like sound waves do. There's a mish-mash of horizontal and vertical components to these vibrations, but when light waves strike a uniform horizontal surface they are reflected with a strong, horizontal polarisation. The glare we experience is the jam of light waves all vibrating in the exact same plane. Sunglasses fitted with a polarisation film eliminate this kind of glare by only enabling vertically polarised light to pass through.

Safeguarding your vision

The ins and outs of how your sunglasses keep your eyes from harm

Anti-reflective coating
Sits closest to the eye and reduces back-glare and internal reflections off the lenses.

Lens (with UV coating)
Infused with organic dyes and metallic oxide pigments, which absorb and reflect harmful light.

Mirror coating
The first line of defence: an ultra-thin coat of reflective molecules deflects the light in bright conditions.

Polarising film
Eliminates glare from polarised light coming off horizontal surfaces like bodies of water and road surfaces.

Scratch-resistant coating
A hard, durable polymer film that protects the surface of the lenses.

UVA rays
They damage the eye's lens and can harm the sensitive retina at the back of the eyeball, causing macular degeneration and permanent blindness.

UVB rays
These rays can destroy the outer cells of the cornea – the eye's protective surface – causing pain and blurred vision.

Visible light
The portion of the electromagnetic spectrum that we can see.

Selecting your perfect pair

UV damage is cumulative, meaning it's never too early – or too late – to start protecting your eyes from the Sun. The most important thing is to choose sunglasses that offer 100 per cent UVA and UVB protection, just as you would with sunscreen. The larger the frame you pick out, and the more they hug your face, the less stray light will reach your eyes from around the edges. Many people mistakenly believe that the darkness of the lenses is what protects their eyes. In fact, some clear transparent lenses can offer full UV protection, but those with a tint will cut out some portion of the light in the visible part of the spectrum too. Different tints offer various advantages – for example, some provide sharp definition while others reduce glare and increase contrast. Finally, if you intend to spend time on the water, beach or ski slopes – invest a bit more and up your protection level with polarising lenses.

Sunglasses with 100 per cent UVA and UVB protection are a must!

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Smartwatches

Discover how the latest must-have gadget has been developed over the last 75 years

The smartwatch might seem like a brand new invention, but it has actually been around in some form or another for decades. The inspiration for a wrist-based device that could do more than just tell the time is often credited to fictional detective Dick Tracy. A two-way wrist radio first featured in the comic strip in 1946, but by this time the first real-life multi-functional wearable device had already appeared on the scene. Early smartwatches were typically timepieces that doubled as calculators, but as technology developed, more features were added to provide for data storage and wireless connectivity to a phone or PC. Modern smartwatches, such as Samsung's Galaxy Gear and the Apple Watch, can now host apps, monitor your heart rate and even pay for your shopping. Over 373 million smartwatches are expected to have been shipped all over the world by 2020, but we can only speculate about the sort of features these high-tech timepieces will have as we enter the next decade.

Measuring your heart rate

1941
Calculate
The first watch to do something other than tell the time was the Mimo Loga. This slide-rule watch had moveable logarithmic tables that enabled the wearer to make basic calculations when on the go.

1972
LED display
The Hamilton Watch Company made the first electronic digital watch, the Pulsar, with an LED display and 18-carat gold body. In 1975, they also released the first electronic calculator watch.

1980s
Storage
The first watches that could store information included the Seiko D409 with 112- bytes of memory and Casio's Databank series of watches that featured tiny keyboards.

1995
Synced up
The Timex Data Link was the first watch to be able to wirelessly sync with your computer. Special software on your PC flashed in a particular pattern that the watch could translate into data.

1940s | 1970s | 1980s | 1990s

SMART WATCH TIMELINE

Explore the evolution of the technology that you thought was brand new

Inside the Apple Watch

The clever components of the tech giant's Sport device

Strap
The removable strap is made from fluoroelastomer, a synthetic rubber that is flexible and durable

Touchscreen
The retina display is protected by aluminosilicate glass that is scratch and impact resistant.

Antenna
The device's Wi-Fi and Bluetooth capabilities are handled by this tiny component.

Speaker
Used to give you audio directions, reminders and alerts, the speaker is also crucial for taking phone calls.

Taptic Engine
This component provides haptic feedback, delivering subtle vibrations to alert you to notifications.

S1 SiP
Apple's 'system in package' is encased in a protective resin shell, and is the main processor that powers the watch.

Battery
The lithium-ion battery offers approximately 18 hours of typical use on a single charge.

Main body
This houses the sensors that can read your heart rate and a magnet that connects the watch to its inductive charger.

Encoder
A push or twist of one of the watch's buttons is converted into a digital signal that the S1 chip can easily understand.

2000 — Run Linux

The IBM Linux Watch and WatchPad 1.5 were the first devices to run the Linux operating system. The latter also featured a touchscreen, a fingerprint scanner and Bluetooth.

2004 — FM signals

Microsoft's Smart Personal Object Technology (SPOT) watches were released. They received FM radio broadcast signals to display news and weather updates.

2006 — Keep fit

The first sports watch/wearable fitness tracker was Garmin's Forerunner with built-in GPS and the ability to track speed, distance, pace and also calories burned.

2009 — Added SIM

Samsung's S9110 watchphone featured a SIM card so could be used to make calls and texts, and play music. It was also the slimmest device of its kind on the market at just 11.98mm (0.47in) thick.

2013 — The Pebble

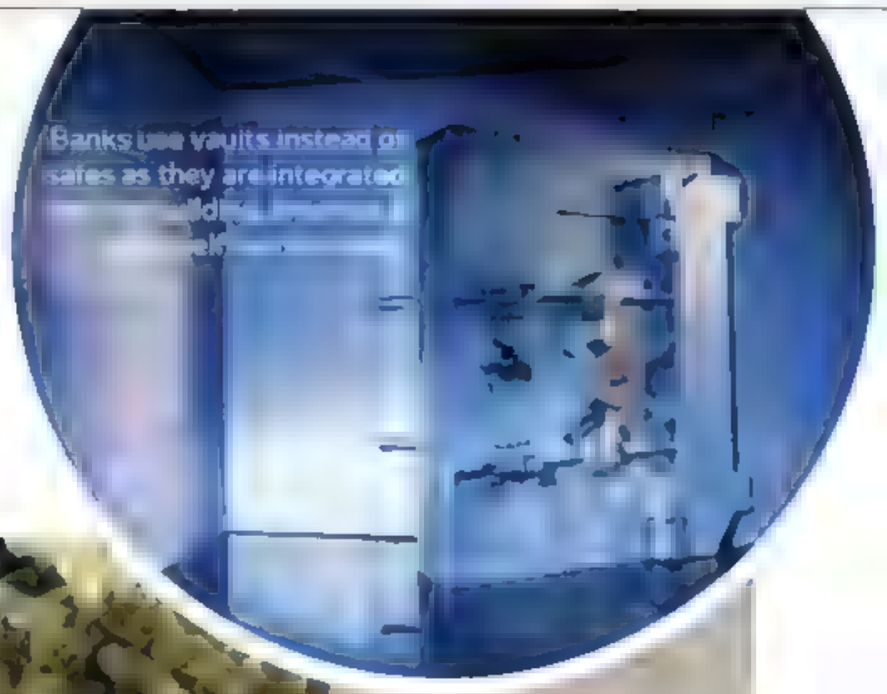
After a successful Kickstarter campaign that raised over £6.5 million ($10 million), the Pebble Watch was released. It has an e-paper display and is compatible with both iOS and Android smartphones too.

2015 — Apple Watch

Following the release of various Android smartwatches, such as the Samsung Galaxy Gear, Apple's highly anticipated smartwatch went on sale with 38 different versions available.

The secrets of safes

How prehistoric fossils can keep your possessions from harm



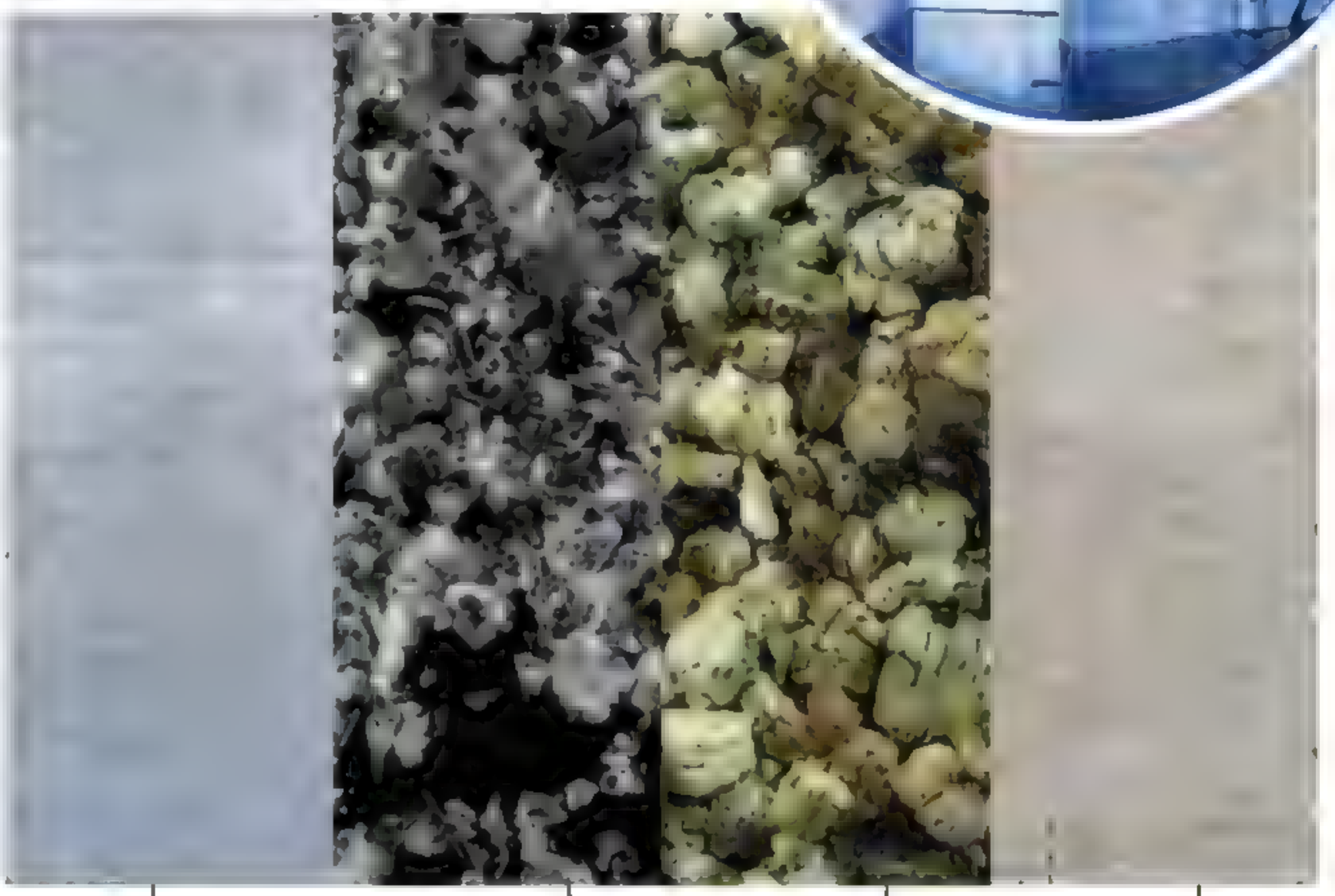
The term "a safe" was first used in the 1800s to describe a chest or cupboard that was not only thief resistant, but could also fend off flames and withstand falling buildings. The modern-day safe still upholds this mantle and has been designed to endure most types of attack.

Today, safes are typically constructed with two pieces of steel that sandwich a specially treated piece of concrete. This concrete has diatomaceous earth (containing prehistoric fossils) and vermiculite added to it, to enhance its strength. There are now a number of different types of lock available to operate a safe's door. Modern day technology such as retina or fingerprint scanning is available, but still comes at a hefty premium.

The most commonly used lock is still the combination variety, which typically requires the user to enter three different numbers to gain access to the treasures that are inside. But the chance of guessing this combination is one in 941,094, making it extremely hard to crack.

How a safe resists damage

See the materials that make a safe both fire proof and thief resistant



Steel
Two thick pieces of steel sandwich together the specially treated concrete layer.

Diatomaceous earth
This earth is rich in silica, which gives the concrete an incredibly high melting point of over 1,700°C (3,902°F), helping it withstand high temperatures without becoming structurally compromised.

Vermiculite
Vermiculite is also mixed in with the concrete which has a popcorn-like structure that helps prevent heat from damaging the safe's contents.

Concrete
Although steel is incredibly tough on its own, the addition of a concrete layer makes the overall structure much harder to infiltrate, especially with a drill.

Why is superglue so super?

Find out how a square inch of superglue can support more than a ton

The compound responsible for superglue's characteristic sticky strength is called cyanoacrylate, which is an example of an acrylic resin. As soon as it is placed on a surface it cures (forms its strongest bond) in an almost instantaneous reaction, requiring only the presence of the hydroxyl ions found in water for this to happen. Nearly all surfaces we encounter have trace amounts of water, as it is present in the air we breathe. This process is an example of anionic polymerisation; the cyanoacrylate molecules link together in a mesh when they come into contact with water, creating a super-strong bond. This differs from the way white glues bond which is by solvent evaporation.

Other than sticking two materials together, superglue can be employed in a variety of other settings. In forensic science, it can be used to visualise latent (invisible) fingerprints, as the superglue's vapours bind to the moisture that is deposited by the fingerprint, turning them white and visible. This reaction also stabilises the fingerprint's detail, making it possible for further enhancement to be carried out. A non-toxic version of superglue has also been created for surgery which can be used to seal the skin without the need for sutures.

This scanning electron microscope image shows superglue's adhesive surface close up

New BMX technology

How tech taken from drones is helping BMX riders log their best times

Ahead of the Olympics in Rio next year, Great Britain's BMX team are tirelessly training to give themselves the best chance of medalling. Every millisecond counts in events such as this, which has led the team to seek help from BAE Systems to see if their advanced tech can help them beat their personal best times.

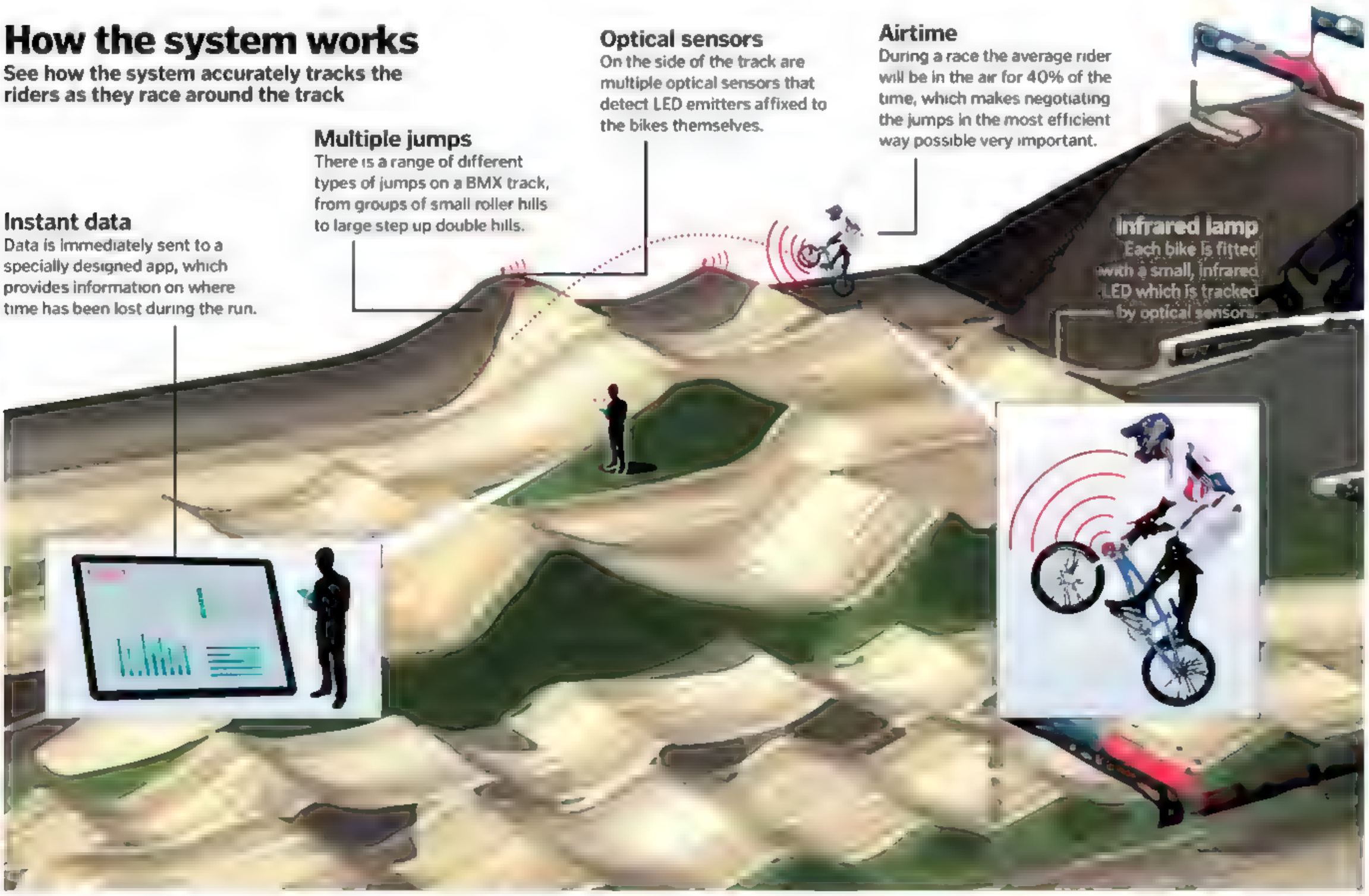
BAE Systems offered a drone from their "sense and avoidance" system, which has been trialled as part of the Autonomous Systems Technology Related Airborne Evaluation & Assessment (ASTRAEA) programme, focusing on tracking objects in the sky. They adapted this technology to provide real-time data of a BMX rider's speed and trajectory, with more accuracy than had been possible before. The riders travel at high speeds during the race, in the region of 40 kilometres (25 miles) per hour. Maintaining these high speeds for as long as possible is vital; it's hoped that the precision of this technology will enable the riders and coaches to see exactly where time and speed is being lost.

The data collated during each run can be used to compare different riders with one another, which can identify what each rider does well and where they could make marginal gains. Prior to the use of this technology, only the overall time of the run was used. Now, the riders are able to review how their speed fluctuates during the run, especially over the multiple jumps.

Riders can immediately assess their performance after completing a lap of the track

How the system works

See how the system accurately tracks the riders as they race around the track



THE SCIENCE OF CUTE

Cute baby creatures are adorable; lambs gambolling in a field, fluffy ducklings in a nest or kittens playing with a ball of wool can make even the hardest soul melt. But what makes the 'oohs' and 'aahs' escape us when cute creatures are around, but not when we're faced with a swarm of bees, for example?

The science behind the cutesy faces is simple: we like baby animals because we are biologically programmed to like human babies, and we need to like our human bambinos so that we take care of them, ensuring the human race lives on.

There are certain features that a lot of baby mammals have in common and these are the triggers that make us go gooey on the inside. Among others, big eyes and fuzzy, podgy bodies push our buttons. Babies have these traits, as do puppies, along with many other things that you might not even notice. Ever wandered past a car and thought it looked cute? Not a coincidence. The manufacturers of the Mini Cooper have thought ahead and made the headlights large, rounded and forward-facing to mimic a pair of large baby peepers and send our cute receptors firing all over the place.

The reason why we love cute things is because they flood our brains with feel-good chemicals. If you're having a bad day, just do a swift internet search for a baby llama and you'll feel better in no time. Interestingly, many people will look at that llama and think it's just so incredibly adorable they could smoosh it up and eat it. This is called cuteness aggression and, although it sounds a bit weird, it's perfectly normal. Your brain senses the cute, but then tries to overcompensate for it! As long as you don't actually take a bite out of the little guy, you're fine.

But why are we so cute? It's because we walk on two legs. Due to our bipedalism, our pelvises shifted, meaning that women can't give birth to anything larger than a baby's head. Our human brains are already disproportionately large, which is why a baby's head is so big and round at birth. This sends our cute response into overdrive and we can't help but want to take care of the mini person forever.

The baby schema

This is a tried-and-tested set of physical characteristics that are almost guaranteed to induce an audible 'aww'. Documented by scientists, these features are based upon the things that we most find adorable on a human baby – the things that provoke our innate desire to take care of something.

Baby schema features also appear on many other animals, most often baby mammals. When we see these visually cute clues, which include big heads, round bodies, large eyes and soft textures, they often elicit the same response – making us want to pick them up, give them a big cuddle and look after them.

Big forehead
Babies heads are large which gives them a big forehead, replicated by the young of other species.

Bobble head
Human brains are disproportionately large and babies' brains are fairly advanced at birth – they have large heads to accommodate this.

Chubby cheeks
A podgy little body and a rounded head give rise to chubby little cheeks that human's can't resist.

Large eyes
A baby's eyes are about 75 per cent the size of an adult's, which is the same as the peepers of countless baby animals.

Soft textures
Baby-soft skin is very cute indeed. So is the soft, fluffy texture of fur or the downiness of feathers.

Round body
A roly-poly body of a kitten is cute to us because human babies are usually chubby.

Kids prefer cute
Even toddlers can recognise 'cuter' faces, according to a study by the University of Lincoln, which manipulated images of faces and analysed the response of children aged 3-6. (*These photos are a representation and weren't used in the actual study.*)


Original Image


Less Cute


More Cute

What cute does to the brain

When we see something that's totally adorable, it captures our attention, brings a smile to our faces and we will more than likely feel compelled to rush up and touch it. This is because it stimulates an area in our mid-brains known as the mesocorticolimbic system. This is the part of the brain that is associated with the processes of motivation and reward. When we look at a sweet bouncing baby, our brains recognise the features that make us relate to our own young (as outlined by the baby schema). This causes a surge of the neurotransmitter dopamine (one that's involved when we fall in love) and makes us feel all warm and fuzzy, which is an enjoyable feeling. Our brains commit that rewarding feeling to memory, letting us know to do it again. The emotional response triggered by the cuteness also stimulates the motivation to care for the animal, hence the urge to pick it up and give it a big old cuddle. This reaction is so ingrained in our human brains that it can be triggered by other things, such as cute little creatures or even inanimate objects with certain features that trigger our 'cute' response!

Baby face
We are programmed to find human babies irresistible, so we look after them and further the development of our species!

Cute features
Seeing big eyes and chubby bodies on other animals triggers the same brain response as seeing a human baby.

Brain action
The mid-brain experiences a surge of feel-good chemicals that make us want to coo over and care for cute creatures.

Evolutionary advantage

Why having adorable babies is essential for some species' survival

In the animal kingdom there are some animals that, once born, charge headfirst into the big wide world without a second look at the parent from whence they came. For example, most insects, reptiles and fish follow this gung-ho approach to infancy. Generally, these types of creatures are notoriously 'not cute'. Although they may have some redeeming features, what the baby schema denotes as 'classically adorable' is largely missing from their profiles. Many other species have an entirely different childhood where they need nurturing and protecting while they grow big and strong – much like our own parental care. It is absolutely no coincidence then that we consider these creatures as much cuter than their more headstrong classmates.

The nature of mammals means that animals are born with plenty of growing left to do. Their features are rounder, noses and snouts are stubbier and there's often a thick layer of baby fat to help cut an even more rotund silhouette. As they slowly grow up, these features elongate and exaggerate and their 'cuteness' fades.

The evolutionary advantage to gradual growth and development is thought to be a sort of trade-off. Where a baby horse can stand up within minutes of being born, it takes a human baby months to even hold itself up. Scientists think that the downside to humans being able to achieve such incredible things in adult life is that it takes us around eighteen years to fully mature – which is a very long time in comparison to our animal friends.

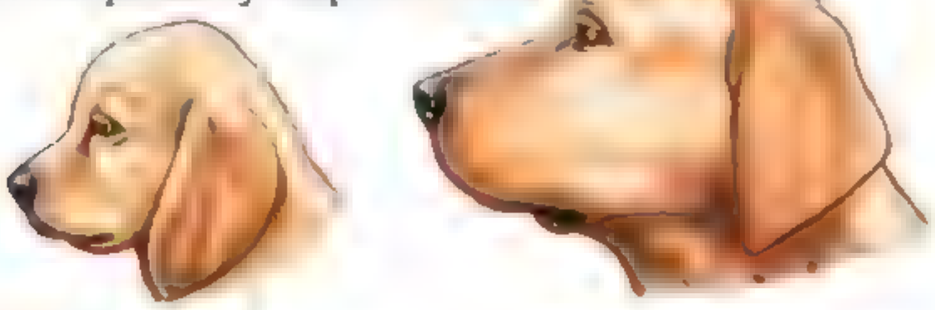
This is why our kids need to be cute and why we need to find them cute! The same is true for the animal kingdom – both humans and animals need to care for their offspring in order to prolong the existence of their species.

In humans, as the cute response is triggered by looking at newborn bundles of joy (or the fluffy animal variety), the neurotransmitters dopamine and oxytocin are released. Associated with the 'reward' pathway in our brains, they also play a key part in social interaction and intimacy – how we bond with other humans. The bond that a mother shares with her baby needs to be strong so that the mother will protect her offspring no matter what. This kind of empathy also enables us to form attachments to our pets!

The cutesy features of an adorable polar bear cub turn most humans to mush

All grown up

The physical changes as little cuties grow into perfectly adapted adults



A dog's life

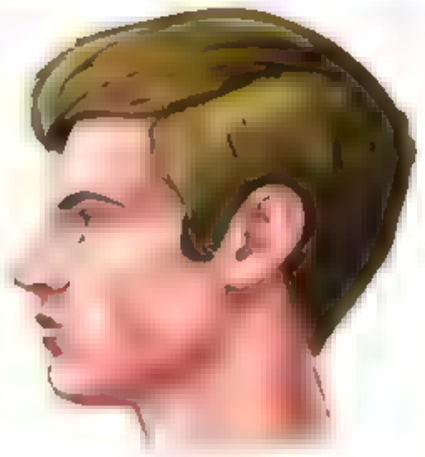
Small dog breeds reach adult size at around one year old. Their heads and snouts extend significantly – an adaptation for housing their spectacular sense of smell and optimally placing their canine teeth.

Hare development

Baby hares (known as leverets) grow quickly. Their rounded faces develop into elongated snouts with large nostrils for sniffing food and big ears for acute hearing.

Boy to man

A baby's eyes are almost the same size that they'll be in adulthood! As a child grows, the skull gradually matures and lengthens – the forehead becomes less pronounced and the face elongates.



Growing birdbrains

Young birds mature quickly. Like other baby-to-adult transformations, their heads and beaks elongate. A longer beak is essential for pecking food.

Illustration by Tom Connell/Art Agency

Instinct and empathy

The urge to care for our young is a result of

As mammals, we have an innate desire to care for our babies. Yet the primal instinct to care isn't always expressed through having our own children. Keeping pets is a good example of this – we empathise with these animals, triggered by the cute response in the brain, and feel the need to care for and nurture them, sometimes as if they were our own children.

Other animals also exhibit this kind of behaviour. There are many stories of unlikely animal companions that have come together, usually when a mother takes on the care of a more helpless creature. YouTube is replete with videos featuring monkeys looking after puppies and kittens. There have even been reported cases of inter-species primate adoption in the wild. For example, a tiny marmoset was witnessed living with a group of larger capuchin monkeys.

There are some species for which the maternal instinct means that if they lose their own baby, the will adopt another. This has been seen in marine mammals such as seals; the mothering instinct can also be so strong that females that have never given birth will foster the young of another individual and care for them, known as 'allomothering.

most unlikely of species.

Mother orangutans [illegible] their babies with them for up to five years

Did dogs evolve to be cuter?

Man's best friend evolved alongside us to be the adorable companions we know and love

Anyone who owns a pet dog will be no stranger to 'puppy dog eyes' – the look our pooches give us that we just can't resist. We know that domestic dogs are descended from wolves and it's also very clear to anyone who's ever set eyes on a labrador, that there are features domestic dogs have that make them far cuter to us. An aggressive wolf approaching a group of early humans with teeth bared is far less likely to be tolerated than a friendly wolf that gives the classic puppy dog eyes. So, it may be that this doe-eyed expression that sends us reaching for the treat jar may have developed as dogs have exploited human preferences. This manipulation tactic may even work so well that it ensures rescue dogs find a new home: scientists studied dogs in shelters and those that pulled certain facial expressions that we find to be cute were more likely to be adopted!

Wolves have much more angular features, with pointy ears, sharp eyes and rougher fur

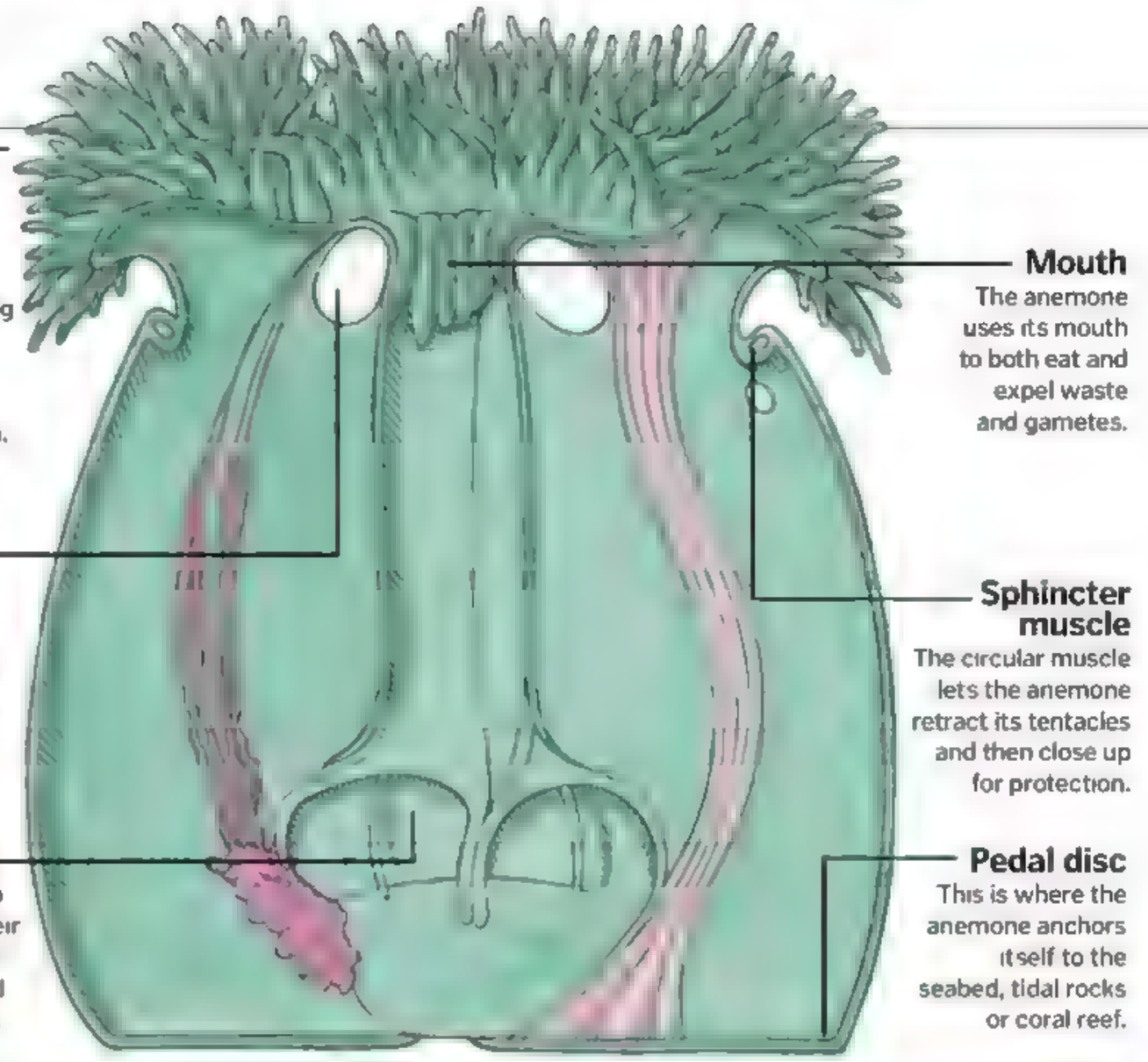
Anatomy of a sea anemone

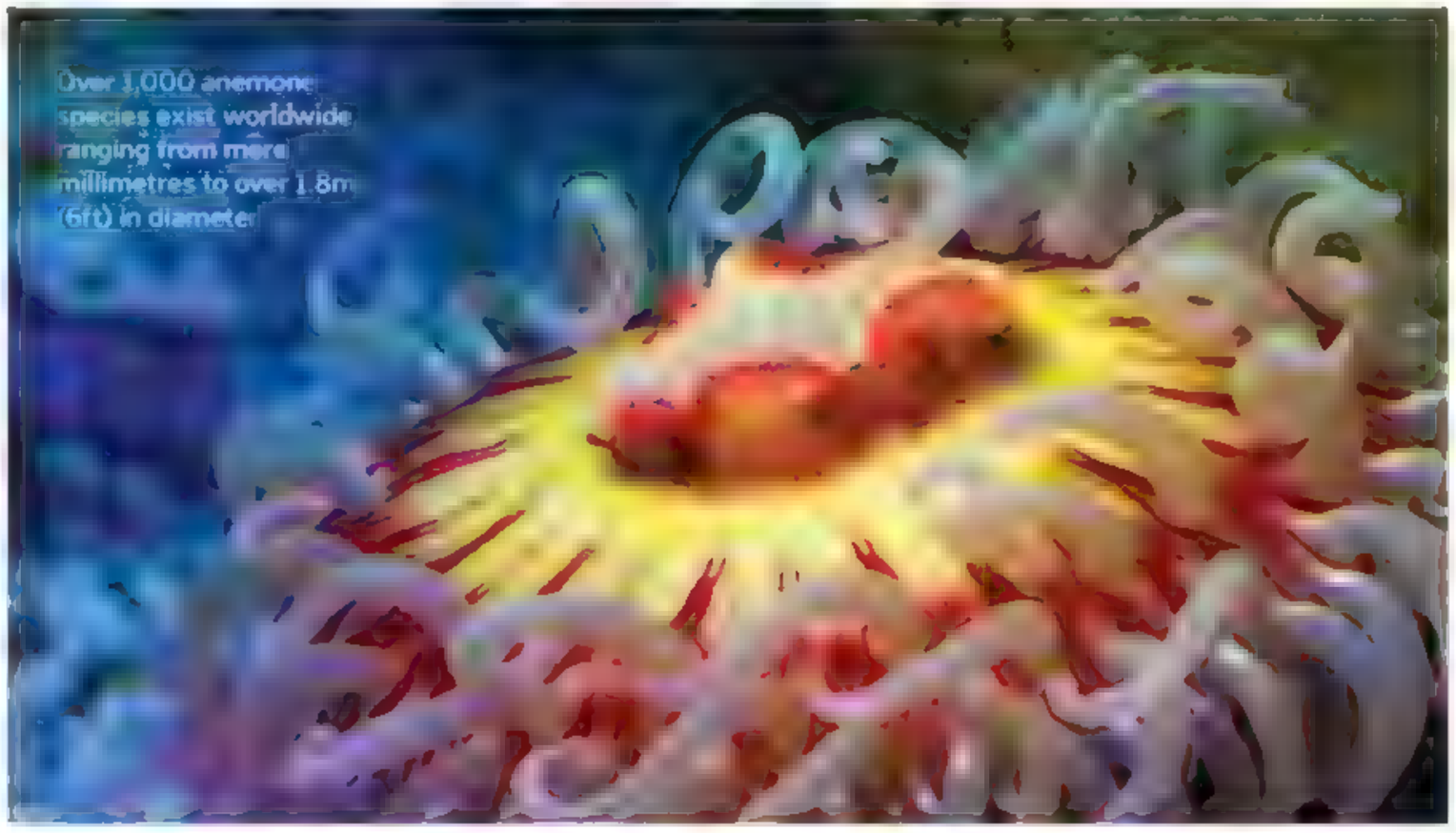
The curious marine critter that looks like a flower but stings like a bee

Found in oceans all across the world, sea anemones belong to the group that also contains jellyfish and coral known as cnidaria. Resembling bright flowers underwater, anemones anchor themselves to rocks on the seabed. Although they have a nervous system, anemones don't have brains.

They have short, cylindrical, radially symmetrical bodies that use hydrostatic pressure to keep their structure. A circle of waving tentacles surrounds the anemone's central mouth and these tentacles contain nematocysts – microscopic stinging structures that use neurotoxins to immobilise prey ready for eating.

The stinging tentacles are dangerous to most marine creatures, but anemones are also known to strike up mutually beneficial relationships (known as symbiosis) with clownfish. The clownfish live in the anemones' tentacles (they are immune to the sting) where they are protected and in return, the fish defend the anemones against any potential predators and provide their hosts with nutrients from their food waste.





Nature's avengers

How wasps attract a mate and get their own back on anyone that harms them

There are around 30,000 described species of wasp in this world. So what if you're a lady wasp, alone and looking for a mate? How do you find your own species to mate with? Researchers have now found that males of a certain species of parasitic wasp have evolved to use specific, genetically led pheromones in order to attract females for courtship.

Pheromones are chemical substances that are released into the environment by animals which can be sensed and interpreted by other creatures. We already know that wasps can communicate using pheromones to let other wasps know the location of food or danger. These newly discovered mating pheromones given off by the male Nasonia wasps let the females know that they are the right species to mate with.

Wasps also use chemical signals to avenge their loved ones. When one is killed or injured, it releases an 'alarm pheromone' that signals other wasps from the nest. This can trigger between 6,000 and 10,000 angry wasps to swarm in defence. Only females can sting and they can do this multiple times.

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The salty soda lake

Discover why Tanzania's colourful Lake Natron is so inhospitable

Situated in Africa's Great Rift Valley, Lake Natron's bright pink waters stand out in more ways than one. In addition to its eye-catching colour, the lake is also hypersaline, meaning that it is supersaturated with salt.

Ash from the once volcanic mountains nearby has enriched the soil on the lake bed with natron, the chemical compound from which the lake gets its name. Natron consists mainly of sodium carbonate, a salt that dissolves in the water to make it strongly alkaline. This type of lake is known as a soda lake, as its water has an extremely alkaline pH of between 9 and 10.5. Acidic rain sometimes reduces this value, but wet weather is erratic in the region.

Additional salts are also fed into the lake from nearby hot springs, and because the lake has no outlet, it is all left behind as the water evaporates. In fact, Lake Natron was originally a much larger freshwater lake, but as the hot, dry climate evaporated much of the water, it shrank and became very salty. The water is also a very warm 40 degrees Celsius (104 degrees Fahrenheit), but can sometimes reach a scolding 60 degrees Celsius (140 degrees Fahrenheit).

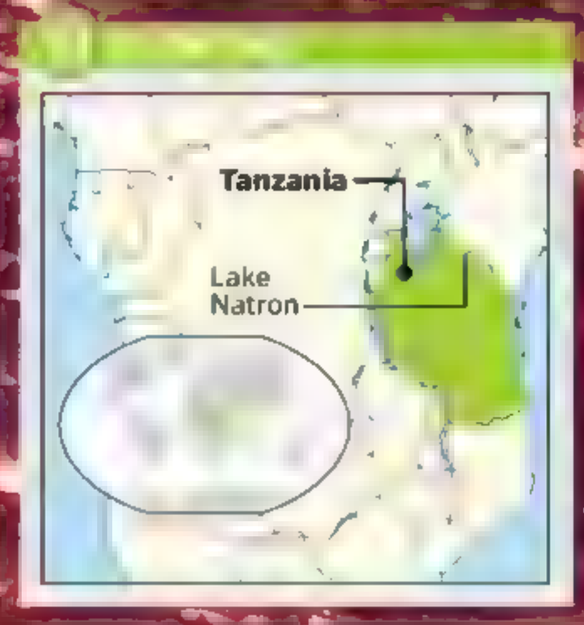
The lake's distinctive colour comes from the microorganisms that thrive on the salt within, but there aren't many other creatures that can survive these extreme conditions. Only one species of fish, the tilapia, is tough enough to live in the lake, but most other animals that venture into the water will die and become encrusted with salts when water levels drop. The natron, which was used in Egyptian mummification, helps to preserve their bodies, causing eerie stone-like figures to occasionally wash up onto the shore. ✪

The lake's salt crust changes colour from red to pink or orange depending on the microorganisms present

The wonderful wildlife of Lake Natron

Three-quarters of the world's lesser flamingos use Lake Natron as their nesting site

"The water can sometimes reach a scolding 60 degrees Celsius (140 degrees Fahrenheit)"



The life of a ladybug

Did you know these beautifully spotted insects begin their lives as grisly grubs?

Animals' lives revolve around eating, and ladybirds are no different. Aphids, or greenflies, are a vital source of food for the 5,000 species of ladybird, but aphid colonies swell and shrink rapidly. Ladybirds time their reproduction with the growth of an aphid population to ensure their offspring will have enough to eat.

There is more on the menu than aphids, however. Ladybirds also feast on plant matter and other insects, but females are more efficient feeders. They are significantly larger than males and are generally more active. They use a lot of energy searching for sites suitable for laying eggs, while males mainly just spend their time searching for females.

To defend against bird predators, ladybird bodies are full of a chemical called precoccinelline. This is toxic, and their red colour acts as a warning to would-be scavengers. The quality of a young ladybird's diet dictates how poisonous it will be as an adult, which is why ladybirds eat up to 5,000 aphids in their lifetime.

Pupal stage
The larva sheds its outer layer of skin to form a cocoon and the transformation begins.

Mature larva
After spending three to six weeks feeding intensively and more than doubling in size, the larva is ready to pupate.

Newly emerged
After seven days of pupating, the insect escapes its cocoon in adult form. It quickly changes from pale yellow to a glossy red.

Freshly hatched
The larvae that emerge are only 2.5 millimetres (0.1 inches) in size. They instantly begin to search for food.

Laying eggs
Ladybirds lay up to 40 eggs at a time, delicately attaching them to the underside of a sheltered leaf for protection from predators.

Mating
After mating, a female ladybird can store male sperm for three months before fertilising the egg.

Hibernation
When the temperature drops, ladybirds seek shelter in which to hibernate, such as tree holes or even inside houses.

Though harmless to humans, ladybirds contain an alkaloid poison that is toxic to birds

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See the leaves for the trees

Yew willow become an expert at identifying leaves with our handy guide

Maple

You might recognise this leaf from Canada's national flag. A maple tree's leaves usually have between three and nine lobes, and are arranged opposite one another on the branches.

Ash

Ash leaves form in pairs; each central stem will bear nine to 13 leaflet pairs with one leaf at the tip. All leaves are pointed and toothed, and have tiny hairs on their lower surface.

Plantain

These form in a rosette formation and range from five to thirty centimetres (two to 12 inches) in length. Generally, they are egg-shaped and are often hairless.

Willow

Willow leaves tend to be long and thin and will alternate along the stem. As they mature, they lose many of their minute hairs and become a duller green on top, while the underside remains silver.

Alder

Each alder leaf will have six to eight pairs of veins which are quite sunken in appearance. These leaves remain on the tree until quite late in the year.

Lime

Lime leaves are generally heart-shaped and in an alternate arrangement. The margin is made up of tiny teeth and the underside has prominent veins protruding from its surface.

Hazel

Hazel leaves are almost completely round other than the section nearest the tip which is slightly pointed. It has a noticeable toothed edge with a hairy underside and stalk.

Acacia

Acacia leaves are classed as compound pinnate, as they form in pairs with a single leaflet at the end of the branch. In hotter countries, acacia stalks flatten to protect the leaves from intense sunlight.

Horse chestnut

Each horse chestnut leaf is narrow at its base but broadens out towards the tip. All the leaves have a central vein that is quite prominent, along with a serrated margin.

Elm

Elm leaves are characterised by their asymmetrical base and the way they taper to a sudden point at the top. They also have a jagged, saw-toothed edge and a rough, hairy surface.

Hawthorn

Hawthorn leaves have a simple structure and tend to have a similar sized breadth and width. Many hawthorn hedges were planted during the Tudor period to mark farmland boundaries.

Sycamore

Sycamore leaves always have five distinctive lobes, along with five veins radiating from the base into the lobes. The leaf edge is quite ragged, with multiple rounded teeth all the way around it.

Clover

The clover leaf is typically trifoliate (has three leaflets) but the current world record is an incredible 56 leaflets! One in ten thousand have four leaflets instead of three, which many consider to be lucky.

Water lily

Water lilies are famous for their round, waxy-coated leaves which sit on top of long stalks. The leaves protrude out of their freshwater habitat and float on the surface.

Cottonwood

Cottonwood leaves have an unusual triangular shape. Their petiole (which attaches each leaf blade to the stem) is a very important feature; it is flattened sideways to enable the leaf to move in a certain way in windy conditions.

Rowan

The rowan tree (mountain ash), has compound leaves with up to 21-paired leaflets. Each has a serrated edge with small teeth and grey hairs underneath.

Strawberry

Strawberry plant leaves typically have three lobes and are dark green in colour. The leaf edge is jagged and curves upwards as the leaf unfurls, before flattening as they grow.

Fern

Fern branches are known as fronds which consist of a stalk with leaf-like growths sprouting from it. These leafy growths have a feathery structure and are commonly known as pinnae.

Celandine

The leaves of the greater celandine are heavily lobed and are a grey-green colour. Celandine leaf is used to form a herbal supplement to treat digestive disorders.

Bramble

Each bramble branch will have between five and seven leaflets growing from it, all of which have a particularly jagged edge. An army of sharp thorns grow on each stem, providing protection.

Red oak

Red oak leaves differ to those of white oaks in their lobe shape – red oaks have pointed lobes rather than round ones. Most red oaks have large leaves that are at least ten centimetres (four inches) in size.

Lilac

Lilac tree leaves are characterised by their tear-drop shape which is rounded near the stem with a long 'drip tip' at the other end. They are dark green, and grow up to almost 13 centimetres (five inches) in length.

White poplar

White poplar leaves typically have a number of irregular lobes, however, those nearest the branch tips have three to five deep lobes. All leaves have a green upper surface and thick hair on the underside.

Elder

Each leaf is longer than it is wide, with a sharply toothed edge and small hairs on the underside. The leave usually feature between five and seven leaflets in an opposite arrangement.

Dog rose

Between five and seven dog rose leaves form in compound pairs along each branch. These leaves are usually hairless and dark green in colour, with a slightly lighter underside.

Beech

Beech leaves have a simple structure and appear alternately along the branches. When they first form, the leaves are light green and have small hairs. Once they mature, they darken and lose the small hairs.

Stinging nettle

The stinging nettle plant has fine toothed, tapered leaves, which can grow to 15 centimetres (5.9 inches) in length. These almost heart-shaped leaves can be eaten when cooked and work well as a spinach substitute.

London plane

Similar in style to the leaves of a maple or sycamore, leaves of the London plane are lobed and veined, with a darker top surface. Before they fall in the autumn, they turn a distinctive yellow or orange colour.

Mission to PLUTO

Pluto has been a world of mystery for nearly a century, but NASA's New Horizons mission will change that

Distant Sun
Pluto is immensely distant from the Sun, which looks like a very bright star in the dwarf planet's sky.

Freezing temperatures
As you would expect for an ice world, Pluto is freezing with a surface temperature of -233°C (-387°F).

Ice
Pluto's surface is covered with ice, mainly nitrogen and methane, with some carbon monoxide ice and other carbon compounds.

An underground ocean?
Deep beneath the surface, Pluto may still be warm enough for the ice to melt and form a liquid ocean.

When the New Horizons space probe blasted off on 19 January 2006, it was going to a planet – the ninth planet from the Sun, in fact. But less than a year later and New Horizons was no longer heading towards Pluto the planet, but towards Pluto the dwarf planet instead. What happened?

Pluto's identity crisis is born out of where it is in the Solar System. It resides in a region called the Kuiper Belt, which is a band of icy comets on the outskirts of the Solar System, beyond the orbit of the ice giant Neptune. It was discovered in 1930 by an American astronomer called Clyde Tombaugh who had been searching for a new planet, using the telescopes at the Lowell Observatory in Arizona. The observatory was the legacy of Percival Lowell, who was on a quest to discover a mysterious 'Planet X' that was perturbing the orbits of Uranus and Neptune.

It seemed pretty obvious following its discovery, that Pluto was too small to be able to affect giant planets like these and in the end it was realised that the perturbations were miscalculations. Still, everyone considered Pluto a planet, although it's really small. Today we know Pluto is just 2,390 kilometres (1,485 miles) across – tiny compared to the next smallest planet, Mercury, which is 4,879 kilometres (3,032 miles) across. It's even smaller than Earth's moon, which has a diameter of 3,475 kilometres (2,159 miles). Even after 1951, astronomers still thought Pluto was a planet and when the first Kuiper Belt objects (KBOs) began to be discovered after 1992, they were tiny compared to Pluto.

But over time the KBOs that astronomers were finding were getting increasingly bigger and it was only a matter of time before something was found to rival Pluto. This happened in January 2005 when a KBO called Eris was found by a team of astronomers led by Mike Brown of Caltech. With an estimated diameter of 2,326 kilometres (1,445 miles), Eris is a tad smaller than Pluto, but is 27 per cent more massive because it contains more dense rock than Pluto does.

So astronomers were faced with a conundrum. Should they call Pluto and Eris planets, or were they something else? In August 2006 the International Astronomical Union – a meeting of astronomers from all over the world – voted to reclassify Pluto and Eris as dwarf planets. This was a controversial decision and many scientists are still against it but as we shall see, Pluto is different from the other planets in many ways.

One big difference is its orbit. The orbits around the Sun of the eight planets in the Solar System are approximately circular, but Pluto's is stretched out like an oval, and for a short part of

"Pluto's identity crisis is born out of where it is in the Solar System"

Thin atmosphere
Pluto has a very sparse atmosphere and the surface pressure ranges between 3 and 100 microbars (3 to 100 millionths of Earth's surface pressure).

Gravity
The surface gravity on Pluto is just 0.6m/s², (2ft/s²) which is about sixteen times weaker than the gravity on Earth.

Charon
Pluto's largest moon, Charon, is only 19,634 kilometres (12,200 miles) from Pluto and the pair are in lockstep, so Charon never moves in Pluto's sky.

Craters
The number of craters on Pluto's surface will tell scientists how old it is and whether it has been resurfaced by geological activity.

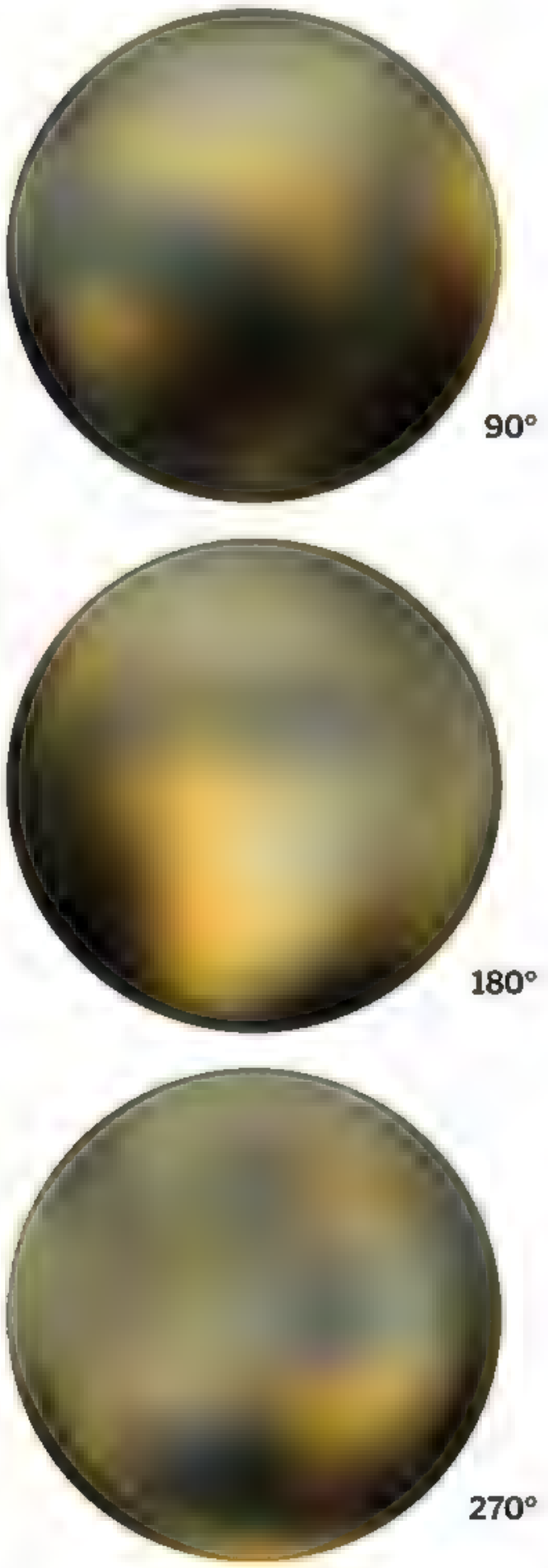
its orbit it can actually go closer to the Sun than Neptune. Its orbit is also inclined to the plane of Earth's orbit, called the ecliptic, by 17 degrees, which is far higher than any of the planets.

Pluto does have moons – five in fact. The biggest is called Charon, 1,207 kilometres (750 miles) across, making it over half the diameter of Pluto. Some astronomers consider them a binary dwarf planet system, rather than a dwarf planet and its moon. The other four moons, called Nix, Styx, Hydra and Kerberos, are thought to be pieces of Pluto that were blasted off in a mighty collision with another large KBO billions of years ago, reminiscent of the giant crash that created Earth's moon. The collision knocked Pluto on its side so that its spin axis is wildly tilted. Pluto and Charon are tidally locked, which means they always show the same face to each other, the same way the Moon always shows the same face to Earth. The other moons tumble along their orbits, destabilised by the shifting gravitational fields of Pluto and Charon.

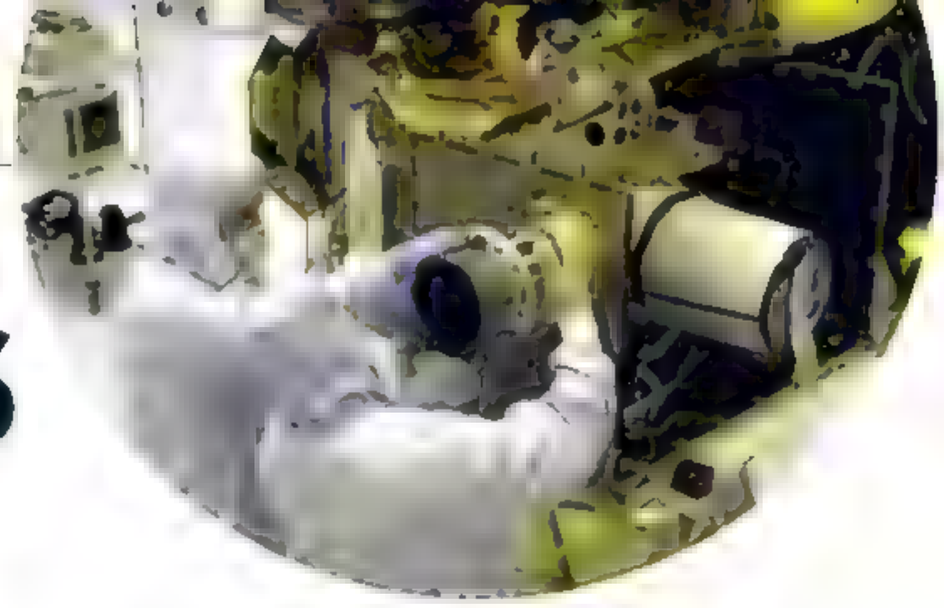
We know very little else about Pluto. We do know that it has a lot of nitrogen and methane ice on its surface and that, when in the sunlight, the methane ice vaporises into a gas that thickens Pluto's atmosphere. As it is so far from the Sun – currently it is 4.9 billion kilometres (3 billion miles) – it gets barely any warmth and its surface temperature is a freezing -233 degrees Celsius (-387 degrees Fahrenheit). However, because methane is a greenhouse gas, Pluto's thin atmosphere is actually warmer than the surface by about 50 degrees Celsius (122 degrees Fahrenheit). The vaporising ice might also lead to geysers of nitrogen spraying up into space from the icy surface, while deep down beneath, there may possibly be an ocean of water.

Why is Pluto camera-shy?

Pluto is a mystery because none of our telescopes are powerful enough to take good images of it, which is why NASA has to send a spacecraft to it. Its angular diameter in the sky when viewed from Earth is just 0.11 arcseconds and the Hubble Space Telescope can see down to 0.04 arcseconds, so Pluto appears less than three pixels across in Hubble's photos. Hubble can resolve Pluto into a disc, but can only see very few details on its surface because those details are smaller than Hubble's resolving power. What Hubble has been able to see is how the light from Pluto changes as the dwarf planet rotates, indicating areas that are slightly darker or lighter, perhaps suggesting some parts of Pluto are icier, and hence more reflective, than other parts. Even then, powerful computer processing is needed to analyse the data and make sense of it, turning it into a rough map.



Hubble's best images of Pluto amount to just discerning regions that are brighter and darker



New Horizons

This summer, one little spacecraft is going to transform what we know about Pluto

Considering that there is so much to discover about Pluto, New Horizons is only going to have a short time to learn it in. Unlike missions such as Cassini that go into orbit around a planet, New Horizons will only be doing a single fly-by, much like the Voyager probes did in the 1970s and 1980s when they flew past Jupiter, Saturn, Uranus and Neptune.

New Horizons isn't going into orbit for two reasons. The first reason is that it approaches Pluto's orbit at nearly 90 degrees, meaning a massive course change would be needed to bring it alongside Pluto's orbit, which it doesn't have the fuel for. The second reason is that scientists want New Horizons to continue onwards after the Pluto encounter and visit another Kuiper Belt object before the end of the century. The fly-by will happen so fast that New Horizons will only get to see one hemisphere of Pluto – the sunlit side. In the few hours that it is making its closest approach of 12,500 kilometres (7,767 miles) from Pluto's surface, New Horizons has a number of goals that it needs to accomplish. Of course, what we want to know the most is what Pluto looks like, so New Horizons' goals include mapping the surface of Pluto and Charon in high-resolution and determining what kind of geology is present. It will also study Pluto's atmospheric composition, discern how much of the atmosphere is being lost to space, look for any undiscovered moons or rings and find out more about Charon and whether it too has an atmosphere.

What about New Horizons itself? Compared to the size of a grand piano attached to a radio dish, its power is provided by a radioisotope thermoelectric generator, or RTG, which provides energy and heat from the radioactive decay of 11 kilograms (24 pounds) of plutonium dioxide. New Horizons only needs about 200 watts to operate.

To manoeuvre, New Horizons has 16 small thrusters mounted on its chassis, using hydrazine as a propellant. Most of the heavy lifting was done at launch, when it became the fastest spacecraft ever launched from Earth at 16.2 kilometres (10.1 miles) per second. With the helping hand of a gravity assist from Jupiter, which it flew past in 2007, New Horizons was sent speeding toward Pluto.

Pluto Energetic Particle Spectrometer Science Investigation (PEPSSI)
PEPSSI will measure the composition and density of gas leaking from Pluto's atmosphere.

Solar Wind Around Pluto (SWAP)
This instrument will measure the rate at which Pluto's atmosphere is being lost to space due to the gusts of the solar wind.

Long Range Reconnaissance Imager (LORRI)
This telescopic camera is being used to image Pluto from long distances in the months ahead of the fly-by.

Star trackers
The star trackers are required for navigation purposes, capable of using the positions of the stars to determine the spacecraft's position, orientation and trajectory.

Venetia Burney Student Dust Counter (located on underside of craft)
Built by students at the University of Colorado at Boulder, this instrument will count the abundance of dust particles in the outer Solar System.

Radio Science Experiment (REX)
Built into the radio antenna, REX will use its radar to measure the temperature and pressure of Pluto's atmosphere.

Visible and infrared imager/ spectrometer (Ralph)
Ralph will map the temperature and composition of Pluto's surface.

Ultraviolet imaging spectrometer (Alice)
Will study Pluto's atmosphere and look for an atmosphere around Charon.

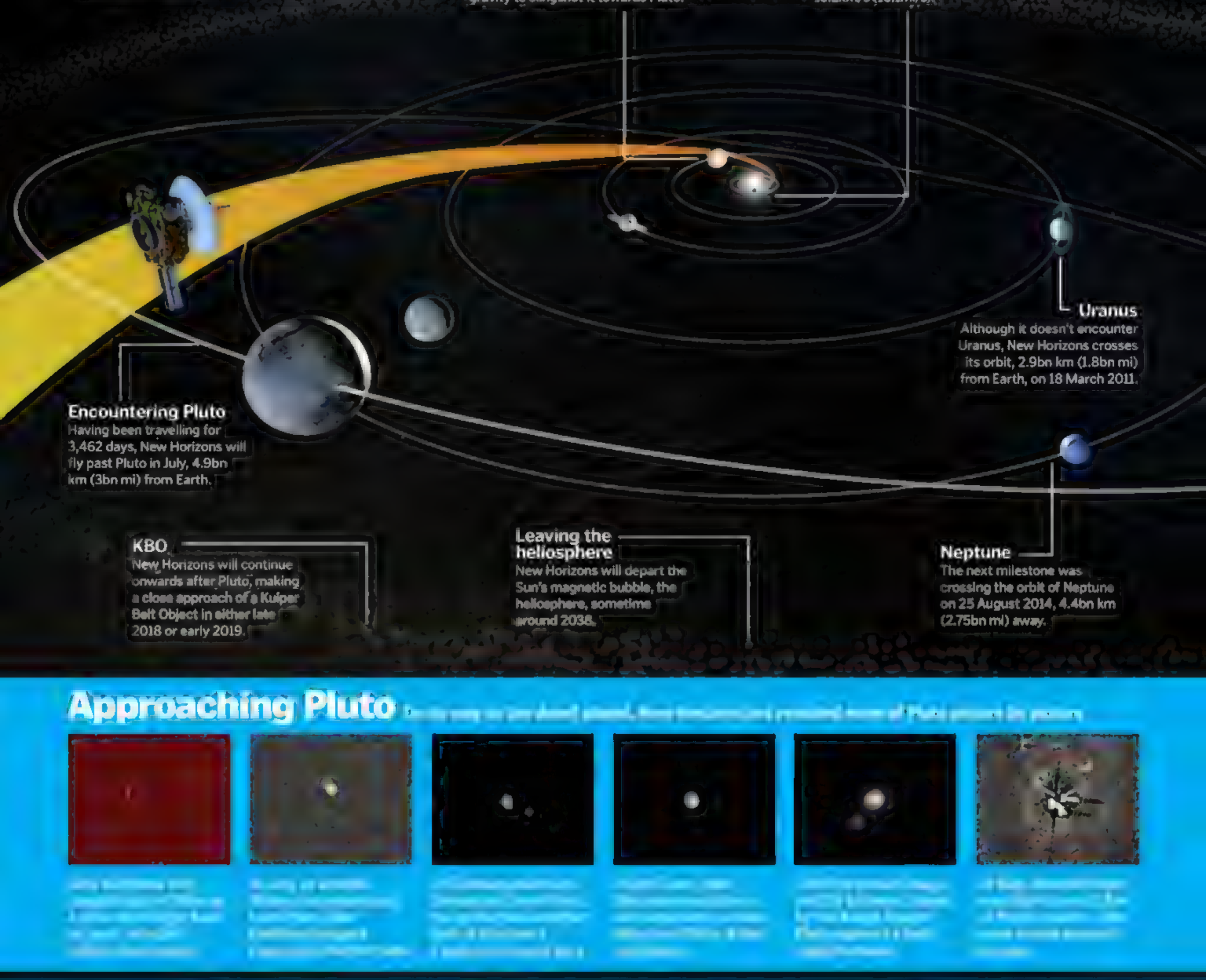
Radioisotope Thermoelectric Generator (RTG)
A nuclear power source to keep the spacecraft powered up.

Technicians attach the 2.1m (6.9ft) radio dish to the spacecraft.

DID YOU KNOW? The Student Dust Counter instrument is named after Venetia Burney, who came up with Pluto's name in 1930

Journey to Pluto

New Horizons' voyage has been a long and arduous one, but this summer it finally arrives at Pluto



Jupiter
In February 2007 New Horizons encountered Jupiter. It imaged the giant planet and the volcanoes on its moon Io, and used Jupiter's gravity to slingshot it towards Pluto.

Launch
New Horizons blasted off and left Earth on 19 January 2006, moving at 16.2km/s (10.1mi/s).

Uranus
Although it doesn't encounter Uranus, New Horizons crosses its orbit, 2.9bn km (1.8bn mi) from Earth, on 18 March 2011.

Encountering Pluto
Having been travelling for 3,462 days, New Horizons will fly past Pluto in July, 4.9bn km (3bn mi) from Earth.

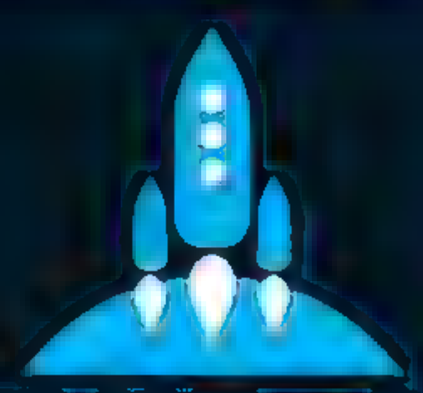
KBO
New Horizons will continue onwards after Pluto, making a close approach of a Kuiper Belt Object in either late 2018 or early 2019.

Leaving the heliosphere
New Horizons will depart the Sun's magnetic bubble, the heliosphere, sometime around 2038.

Neptune
The next milestone was crossing the orbit of Neptune on 25 August 2014, 4.4bn km (2.75bn mi) away.

Approaching Pluto

4.5 hours
Time it takes for signals from the spacecraft to reach Earth



58,338km/h
New Horizons was the fastest spacecraft ever launched

Circa $700 million
The total cost of the mission from 2001-2016

2,390km
Pluto is only about half the width of the USA

The deadliest planet

Of all the planets in the Solar System, Venus is the worst place to live: hot, oppressive and toxic

Greenhouse effect
The reason Venus is so hot is its atmosphere, 96.5 per cent of which is composed of carbon dioxide, which is a deadly greenhouse gas.

Acidic atmosphere
Lacing the atmosphere are clouds of sulphuric acid. On Venus, the acid rain is enough to kill you.

Volcanic world
There are more than 1,600 volcanoes covering the surface of Venus, with evidence that some of them have violently erupted in the recent past.

Suffocation
With all the carbon dioxide and sulphur, there is no room for oxygen to breathe.

Hotter than hell
Venus is the hottest planet in the Solar System, with scorching temperatures of 460 degrees Celsius (860 degrees Fahrenheit) – hot enough to melt lead.

Crushing pressure
The pressure of the air at the surface is 92 times greater than on Earth. Space probes that have landed on Venus have been literally crushed.

Dehydration
Venus is bone dry - almost all its water molecules have escaped into space, or been split apart in the upper atmosphere.

The spiders from Mars

These aren't David Bowie's backing group, but creepy patterns found in Martian ice

An artist's impression of the geyser on Mars that makes the spider.

Spider patterns seen at Mars's south pole by NASA's Mars Reconnaissance Orbiter.

At Mars's south pole, in the middle of winter, the temperature can plummet as low as -125 degrees Celsius (-193 degrees Fahrenheit), which is chilly enough for carbon dioxide gas in the atmosphere to freeze out as a layer of dry ice (what we call frozen carbon dioxide). When spring comes around, this frost evaporates explosively! The darker ground below the dry ice absorbs the warmth of sunlight at a faster rate than the ice does. The warmer ground warms the dry ice from the bottom up, causing it to turn back into carbon dioxide gas – a process called sublimation. As the gas heats up it expands and forces its way through the ice above, burrowing its way to the surface by carving out channels that converge at a spot where the gas and dirt it carries with it burst out into the air as a geyser of dirty carbon dioxide gas.

It is these channels, some of which are 300 metres (984 feet) across, that create the impression of a spider web. Scientists suspect that the dwarf planet Pluto might also have spiders, formed by geysers of nitrogen instead of carbon dioxide. Pluto has a bright ice cap that is in sunlight at the moment, and the New Horizons spacecraft will be looking for the spiders from Pluto when it flies past in July.

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Active galaxies

The powerful galaxies that swallow their surroundings

A galaxy is a large system of stars, gas, dust and dark matter bound together by gravity. Most normal galaxies emit light from their stars, but a small number give off an enormous amount of energy from their centre in wavelengths of light that are invisible to the naked eye. These are known as active galaxies and their energy emission is driven by supermassive black holes at their core. Such black holes actually lie at the centre of every large galaxy, including the Milky Way, but most are now inactive. This has led many scientists to believe that all galaxies in fact started out as active.

Formation

How a galaxy goes from being active to inactive

1 Supermassive black hole
Small, stellar black holes form when large stars collapse, but the origin of their supermassive cousins is still a mystery.

Speeding swirls
The matter within the jets spirals into outer space at speeds approaching the speed of light.

2 Even more massive
Once the supermassive black hole has formed, it accumulates gas and dust to grow in size.

3 Visible halo
A swirling cloud of matter, known as an accretion disk, forms around the black hole, feeding it more gas and dust.

4 Powerful jets
Just before it is pulled into the black hole, some of the matter is ejected outwards in two jets that align with its poles.

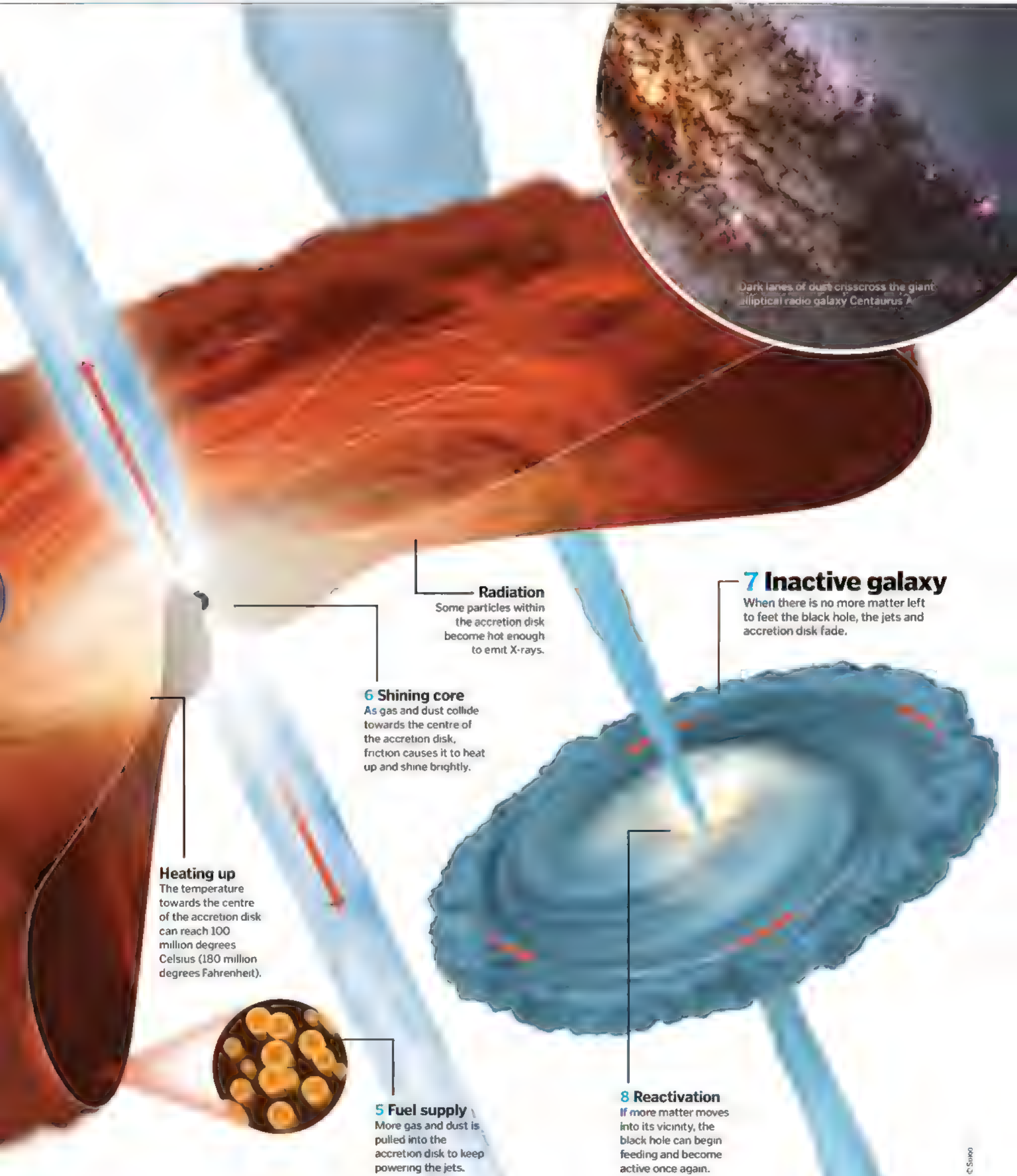
Three Types of active galaxy

A Quasars
These are located billions of light years away from Earth and viewed from an angle.

Radio galaxies
These galaxies are viewed from side-on so the core cannot be seen

Blazars
These galaxies have one jet pointing towards Earth so that we are looking at it head-on

"Stellar black holes form when large stars collapse"


Dark lanes of dust crisscross the giant elliptical radio galaxy Centaurus A
Radiation
Some particles within the accretion disk become hot enough to emit X-rays.
6 Shining core
As gas and dust collide towards the centre of the accretion disk, friction causes it to heat up and shine brightly.
7 Inactive galaxy
When there is no more matter left to feet the black hole, the jets and accretion disk fade.
Heating up
The temperature towards the centre of the accretion disk can reach 100 million degrees Celsius (180 million degrees Fahrenheit).
5 Fuel supply
More gas and dust is pulled into the accretion disk to keep powering the jets.
8 Reactivation
If more matter moves into its vicinity, the black hole can begin feeding and become active once again.

THE AMERICAN CIVIL WAR

The fight for liberty, justice and one nation's soul tore the USA in two and redefined its destiny

On 12 April 1861, the garrison of Fort Sumter in the US state of South Carolina, came under artillery attack. This was no foreign invasion, however, but an army of fellow Americans bent on taking the fort – the first shots of the Civil War had been fired. For the next four years America would be plunged into a state of war with itself. The conflict would prove to be simultaneously the most turbulent and redefining period of American history since the Revolutionary War in the previous century.

On one side were the states collectively known as the Union, located mainly in the northern regions of the USA, including Maryland, Pennsylvania and New York. On the other side was the Confederate States of America, comprising of Southern states including Virginia, South Carolina and Mississippi.

Hundreds of thousands of men from each side volunteered to fight and thousands were also later conscripted or forced into the army as the need for fresh recruits grew. The Union ranks numbered many recent immigrants, such as German and Irish, and later around ten per cent of these forces were made up of African American soldiers. Confederate forces, on the other hand, were almost entirely white and native-born Americans.

The war saw some of the most devastating battles ever in American history, such as Antietam and Gettysburg, nearly all of which were captured on film by some of the first war photojournalists. The states of the Union possessed much more manufacturing capacity than the Confederacy and had a far stronger economy. However, the southern states could rely on their geographically huge territory which would prove very difficult for an invading army to keep control of.

How did the war start?

Why the United States slowly broke apart and slipped into open war

In the 19th century the southern USA was made up of so-called slave states, where owning and trading slaves was legal. After Abraham Lincoln was elected President in 1860, many of these states feared he would make slavery illegal across the country. Much of the economy in the south was based around plantations, predominantly producing cotton, which relied heavily on slave labour.

To avoid losing what they saw as an inherent right to keep slaves, these states quickly voted to secede or split from the Union and go it alone. By February 1861, Alabama, Georgia, Louisiana, Florida, South Carolina and Mississippi formed what became known as the Confederate States of America. Soon this Confederacy appointed its own provisional president, Jefferson Davis, and made hasty preparations for a coming conflict with the north. Though some slave states also existed in the north of the country, such as Delaware and Maryland, they opted to remain within the Union.

President Lincoln condemned the Southern states' secession from the Union calling it illegal, and though he made desperate efforts to save the Union, it was already too late. Soon after his inauguration in March 1861, the attack on Fort Sumter sparked open warfare between the north and the south. The Civil War had begun.

Battle of Antietam, the charge of the Iron Brigade near the Dunker Church, on September 17, 1862.=

Above all though, the Confederacy just needed to survive to maintain its independence. The Union, meanwhile, had to wholly defeat its enemy to restore the United States to its former self. It would not be until 1865, at Appomattox Court House in Virginia, that Robert E Lee surrendered his army to a superior Union force under Ulysses S Grant. Just five days after the surrender of the south, President Lincoln would be assassinated by an outraged Confederate supporter. The man who oversaw the war that transformed an entire nation would be among its final victims.

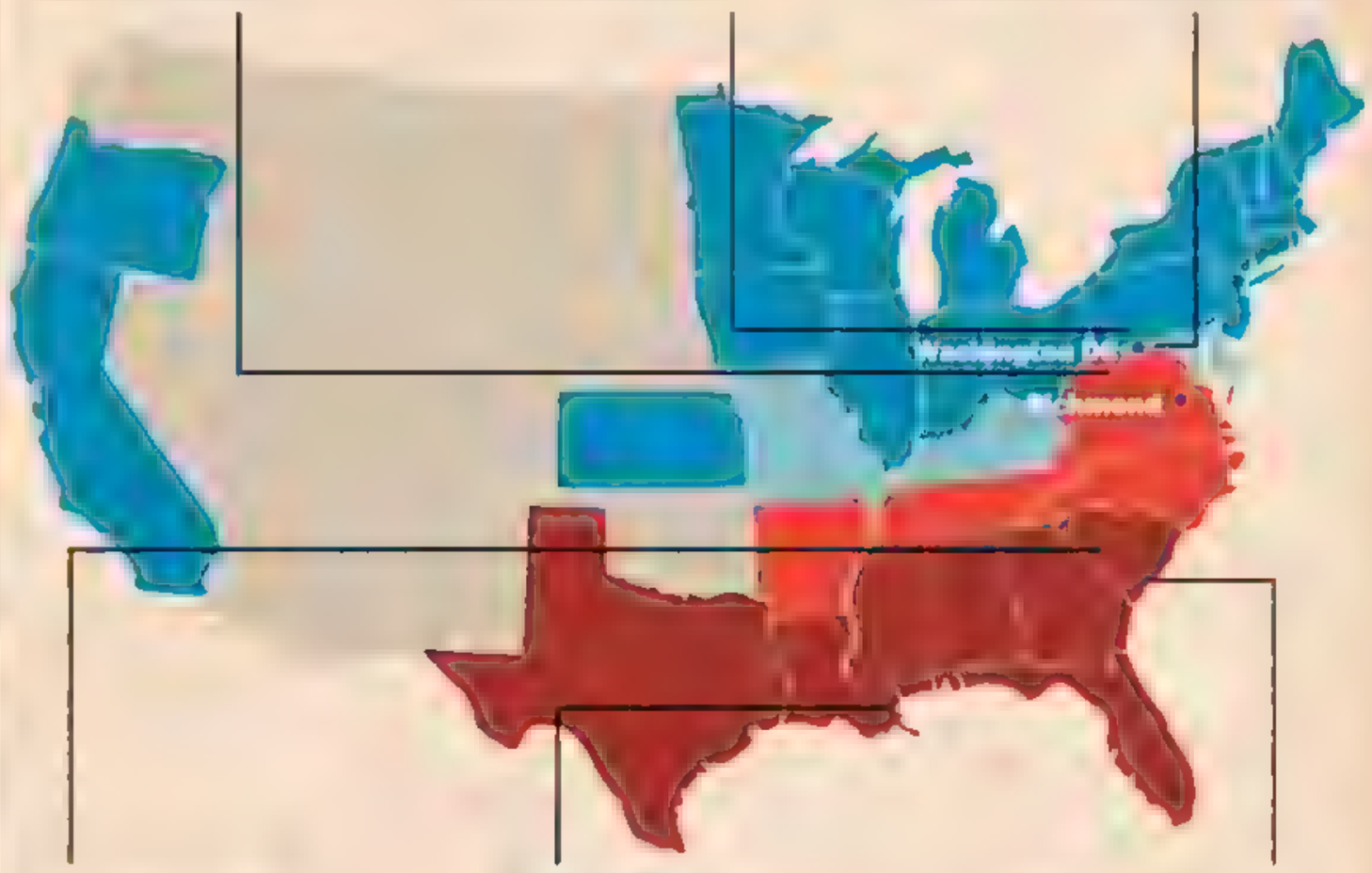
A country divided

After the presidential election of 1860, several southern states voted to split from the USA and became independent

Battle of Bull Run
Confederate and Union soldiers clash for the very first time near the Manassas railroad junction, north Virginia. It is a damning defeat for the Union.

The Battle of Gettysburg
Considered one of the great turning points of the war, a Confederate invasion into the north is crushed by the Union army in Pennsylvania.

The Battle of Antietam
After Robert E Lee crosses the Potomac river into Maryland in September 1862, the bloodiest battle of the war results in a stalemate, but the Confederates retreat back into Virginia.



The Union breaks
On 20 December 1860 South Carolina was the first to secede (or break) from the Union. Several others would follow in the coming months.

The Union take New Orleans
In an attempt to cut off the Confederacy from the sea, a squadron of Union troops take New Orleans, Louisiana.

War begins
The first shots of the Civil War are fired on 12 April 1861, as a Confederate force attacks the federal garrison of Fort Sumter.

- States that seceded before April 15, 1861
- States that seceded after April 15, 1861
- Union states that banned slavery
- Union states that permitted slavery

Soldiers of the Civil War

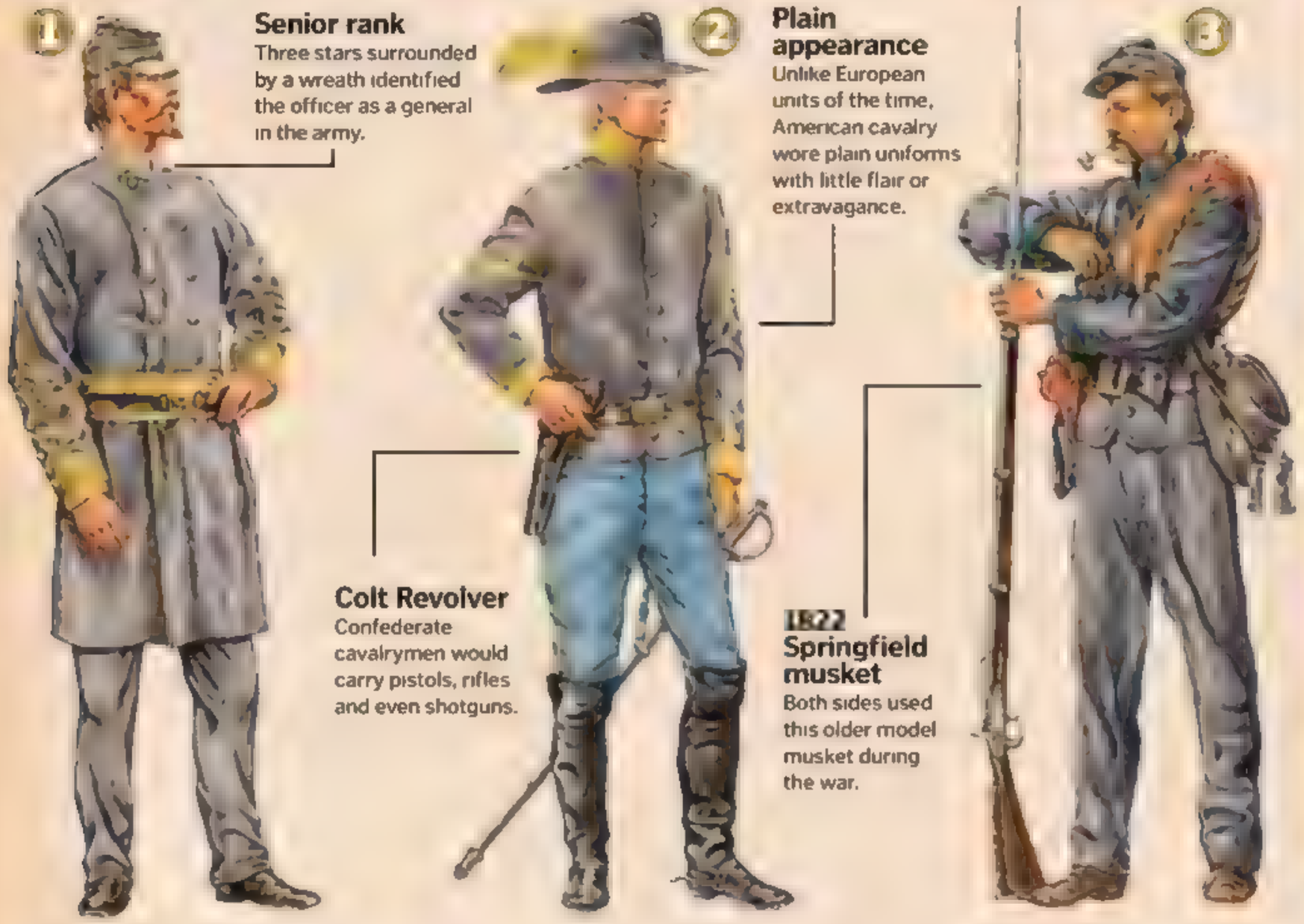
Both Confederate and Union armies fielded a variety of soldiers on America's battlefields

Confederate

1 General
Watching carefully from the sidelines but occasionally throwing themselves in harm's way, each side's generals commanded the respect and loyalty of their men. Generals on both sides were commonly graduates of the West Point military academy and, like Robert E Lee and Ulysses S Grant, knew one another well.

2 Cavalry officer
Immensely flexible and lightning quick, cavalry units remained a devastating element of warfare in the 19th century. Mounted troops were tasked with scouting territory, raiding enemy camps, as well making wide flanking manoeuvres to gain the upper hand. Riders could dismount, fire off a few rounds from their weapons, then ride away again before the enemy could respond.

3 Infantry volunteer
Most Confederate soldiers were recruited from among the poor farmers and labourers of the south, with little or no experience of war. A lack of resources and supplies, even food and clothing, meant many recruits had to improvise their own uniforms. Many simply wore whatever clothing they owned already, making them appear rough and ragged.



1 Senior rank
Three stars surrounded by a wreath identified the officer as a general in the army.

2 Plain appearance
Unlike European units of the time, American cavalry wore plain uniforms with little flair or extravagance.

3

Colt Revolver
Confederate cavalrymen would carry pistols, rifles and even shotguns.

1822 Springfield musket
Both sides used this older model musket during the war.

Union

1 Standard bearer
Carrying the standard was a great honour for a soldier. These flags often featured bespoke designs symbolising the regiment, as well as the state and the city the soldiers belong to. This made it essential to protect it during battle and capturing the enemy's standard was a great victory.

2 Sharpshooter
Armed with incredibly accurate guns, such as the Colt five-shot revolving rifle, the deadly aim of a single talented marksman was worth 50 shots of a standard volunteer soldier. These men were often hand-picked from all over the country for their proven accuracy with a rifle.

3 Zouave infantry
These light infantry volunteers were recklessly brave in battle and wore incredibly flamboyant clothing that made them stand out from other soldiers. Taking their style from French colonial soldiers in north Africa, Zouave regiments were among the first to fight in the Civil War and featured in every major battle.

Defenceless
When both hands were gripping the flag, the standard-bearer was left almost helpless.

Standard-issue rifle
Far more accurate than the standard muskets of the day, rifles also had a longer range.

Bright dress
The Arab-inspired colourful cap was a traditional garment from the French Zouave infantry.

Green coat
The United States Sharpshooters wore green coats to signify their elite status.

Images by Hemesh Alles/Art Agency

Weapons and equipment

All the latest technology of the century was pressed into service by each side of the war

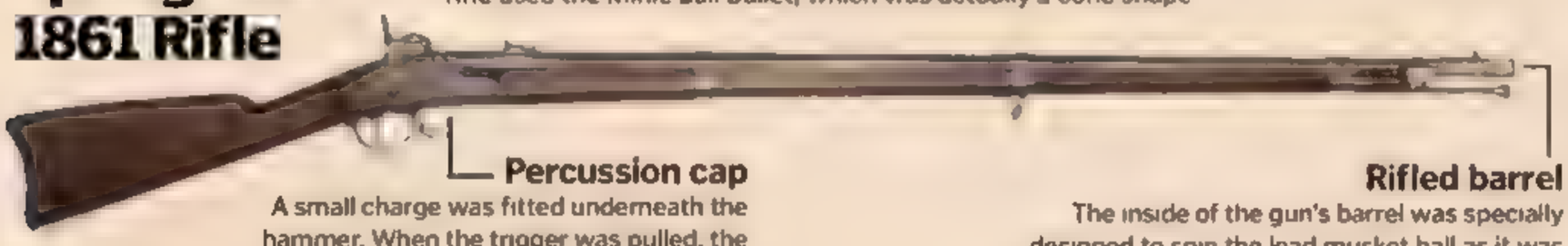
America's Civil War is considered by many to be the first truly modern conflict, where the new and exciting technology of the day would play its own part. It was one of the first wars to be captured on camera by photojournalists, so the very real horrors of the battlefields could be seen by ordinary members of the public. Far deadlier innovations also made their debuts in the war, such as the first machine gun – the Gatling – though the destructive potential of this weapon wasn't fully appreciated until some years after the conflict had ended.

Ironclad warships did battle at sea for the first time ever, while early submarines were first used to attack enemy vessels from beneath the waves. Away from the frontline, however, the ordinary inventions of the time were all pressed into service for the war effort. The USA's flourishing rail networks were used to transport troops across the vast country, meaning generals could reinforce regions and gather reinforcements far quicker than ever before. During the First Battle of Bull Run, Confederate defenders in Virginia were able to push back the Union attack, because reinforcements quickly brought in via train helped to boost the numbers on the frontline.

Most important for ordinary soldiers on the ground, however, was the development of ever more powerful and accurate rifles. Gunsmiths would shape spiral grooves into the inside of a gun barrel, known as rifling, to effectively spin the bullet as it was fired. This improved the overall accuracy of shots compared to those fired by a conventional musket, resulting in a whole new breed of sharpshooters on battlefields.

Springfield 1861 Rifle

Perhaps the most famous gun of the Civil War, the Springfield rifle used the Minié ball bullet, which was actually a cone shape



Percussion cap
A small charge was fitted underneath the hammer. When the trigger was pulled, the hammer ignited the cap sending a flame down into the black powder in the barrel.

Rifled barrel
The inside of the gun's barrel was specially designed to spin the lead musket ball as it was fired. This processed is called rifling and is still used today to make guns more accurate.

Colt Army Model 1860

Samuel Colt's 1860 revolver was among the most popular handguns of the war

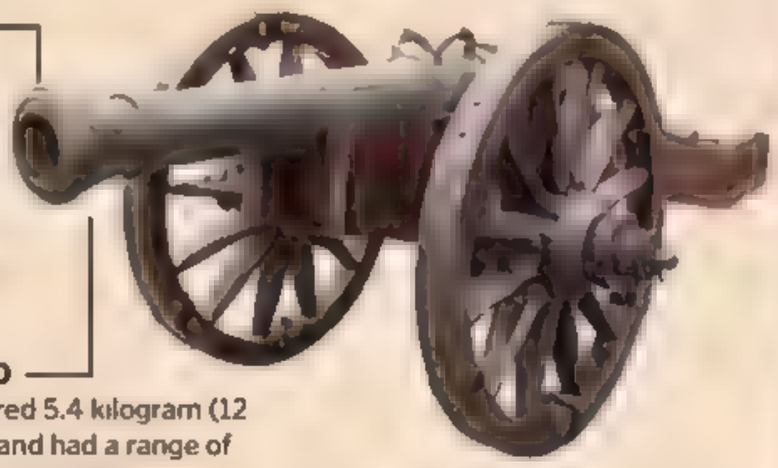
Six-shooter
Six .44-calibre bullets could be loaded into the gun's cylinder, and the hammer had to be pulled back each time after firing to rotate a new bullet into the chamber.

Iron sight
A small sight near the muzzle of the gun helped with aiming. The weapon was accurate up to around 69 metres (225 feet).

Model 1857 'Napoleon' cannon

Napoleon cannons were used by both Confederate and Union batteries and were among the most common artillery weapons of the war

Smoothbore
Named after the French emperor Napoleon III, the barrels of these guns did not have rifling, so were completely smooth on the inside.



12-pound ammo
The Napoleon guns fired 5.4 kilogram (12 pound) cannon balls, and had a range of nearly 1.6 kilometres (one mile).

Bowie knife

This deadly weapon was named after the famous explorer Jim Bowie

Self-defence weapon
Popular among Confederate soldiers at the beginning of the war, the knife soon became obsolete as bayonet designs became more prominent.

Cutting blade
The knives were commonly 20-30 centimetres (8-12 inches) long and up to five centimetres (two inches) wide, making them ideal for hand-to-hand fighting or for hunting.

Ketchum grenade

The Ketchum grenade was designed to explode when it landed nose first, although it was often unreliable

Short flight
Originally the grenades were attached to wooden flights, making them shaped almost like darts that helped them to land on their nose.

How to fire a rifle

In war the ability to load, aim and fire not only accurately but also quickly often meant the difference between life and death

1 Load the gun
The minié ball and powder are kept in their own paper casing, so rip open the case and pour the black powder down the end of the barrel, known as the muzzle. Next, drop the ball into the muzzle.

2 Ram down the bullet
Take out the ramrod and insert it into the barrel flat end. Press the bullet and powder down with the ramrod to pack them into the rear of the barrel. Remove the ramrod and put beneath the muzzle.

3 Insert the percussion cap
Take one percussion cap and insert it soft-side down onto the metal nipple protruding from under the hammer. Make sure the hammer is half-cocked when you do this, to avoid a misfire.

4 Ready and fire
Pull back the hammer to the half-cocked position, then back to fully cock it. Now you can aim and fire. Don't remove the spent percussion cap, as this could cause powder residue to ignite.

Images by Ed Crooks

The warring presidents

Abraham Lincoln

Jefferson Davis

Inside the Battle of Gettysburg

Robert E Lee's Confederate army faces off against General George Meade's Union force to decide America's fate

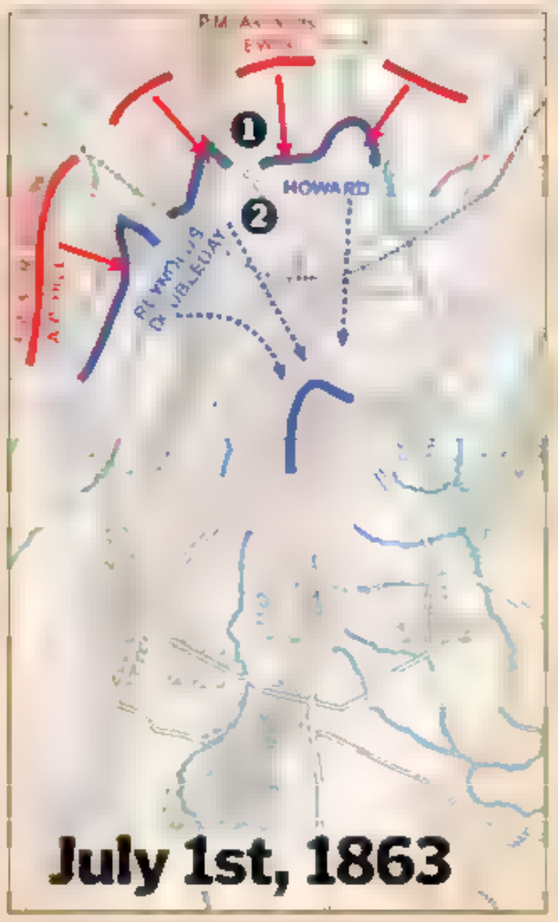
In June 1863 General Robert E Lee, the famous Confederate commander, marched his forces north to invade the Union heartland. He was confident his Army of Northern Virginia, numbering nearly 72,000 men, would defeat the Union's Army of the Potomac and even enable him to attack Washington DC itself.

However, the Union army had followed Lee and his forces and its leader, General George Meade, was determined to destroy them. The two armies finally met at the small town of Gettysburg, in southern Pennsylvania, and soon the most important battle in American history unfolded.

The battle is widely considered the most important of the war, as it prevented the Confederacy from encircling the capital of the United States and possibly forcing an early end to the war. If Lee's plan had worked, the Confederate states split from the Union could have remained independent, the Confederacy could have survived and the USA as we know it would not exist.

How the battle unfolded

What started as a small skirmish near Gettysburg soon escalated into full-blown carnage that lasted three days



1 The two sides meet

Small pockets of **Union** infantry around Gettysburg clash with advancing **Confederate** units, and choose to make a stand to prevent them taking the town.

2 Confederates break through

As 30,000 **Confederate** troops attack only 20,000 defenders, the **Union** line eventually breaks. All the engaged **Union** corps are soon retreating through Gettysburg, with the southerners ruthlessly pursuing them.

3 The Union army reforms

After retreating from Gettysburg, General Meade forms his troops into the shape of an inverted fishhook, with a long straight line facing the **Confederates** to the west.

4 3rd Corps re-positions

Without orders, the **Union** 3rd Corps moves to higher ground towards the west, into a peach orchard and further south to an area known as Devil's Den.

5 The Confederates attack

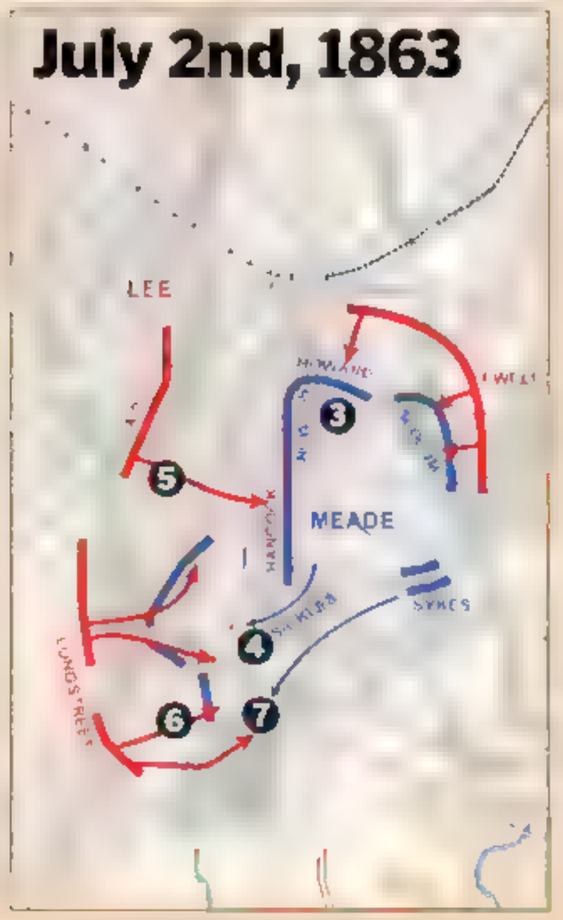
Confederates lined up along Seminary Ridge attack the **Union** left flank and the centre in an attempt to break it.

6 Regiments clash at Devil's Den

The Union 3rd Corps is attacked at Devil's Den, while Texas and Alabama **Confederate** regiments move towards Little Round Top on the **Union** left flank.

The *Gettysburg Cyclorama* by Paul Philippoteaux depicts the Pickett's Charge assault during the last day of the battle

The Army of northern Virginia retreats

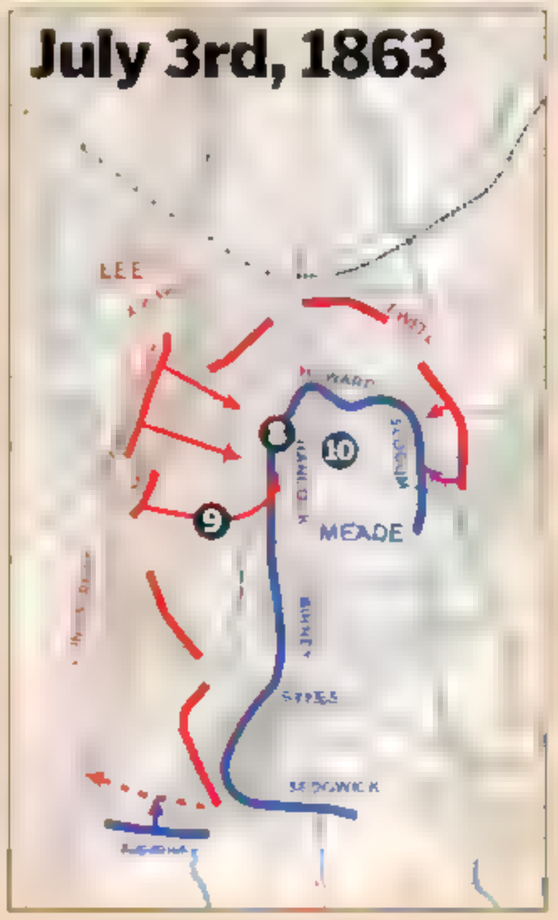


7 Union troops resist at Little Round Top
Union troops on Little Round Top fix their bayonets and charge the **Confederate** troops assaulting up the hill, which sends them running.

8 Both sides recover
At the end of the 2 July, **Union** troops hold a defensive line along Cemetery Ridge, Cemetery Hill and south to Little Round Top as well.

9 Pickett's charge
On 3 July the **Confederates** attack the **Union** centre with an artillery bombardment and 12,000 soldiers, but they are repulsed and forced to retreat.

10 The Confederates retreat
As the **Confederate** army retreats, the **Union** force maintains its position on Cemetery Ridge and Hill.



© Maps by Hal Jespersen, www.cwmaps.com

The Chapel of Bones

Thousands of human remains were used to create this spooky monument to the dead

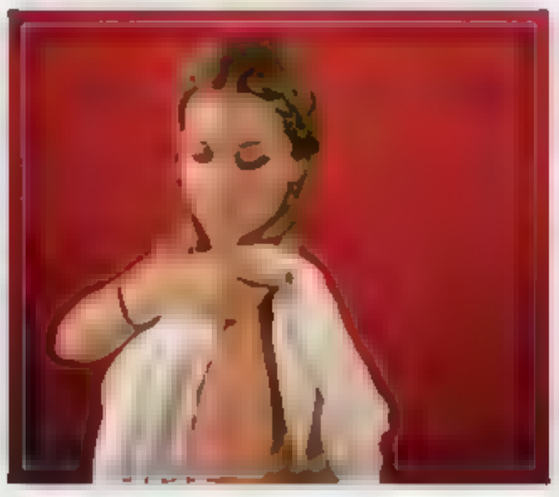
The outside of St Francis Church in Evora, Portugal looks just like any other Renaissance church. But step inside and you will discover a dark secret hidden within its walls – a chapel made out of bones. The Capela dos Ossos, or 'Chapel of Bones', was built by a group of Franciscan monks in the 16th century. When the city's cemeteries became overcrowded, the remains of thousands of deceased people were brought to the church for storage. This was normal practice for the time, but rather than hide them away in underground tombs, the monks decided to put the bones on display. They believed that this monument would help to remind their fellow brothers of their own mortality.

The walls and central pillars of the chapel were covered with cement, and then the bones and skulls of around 5,000 skeletons were pressed into them. Two desiccated corpses were also hung from the ceiling by ropes. No one really knows who these two skeletons belong to, but some people believe they are those of an adulterous man and his son, cursed by a jealous wife.

How to tie a toga

Turn a bed sheet into an authentic Roman costume with these simple steps

1 Wrap it around
Take a large bed sheet and fold it to the length you want your toga to be. Then wrap it around you like a towel. Bring one corner around your back and up to your left shoulder.



2 Tie at the shoulder
Adjust the sheet so that it is the right height for you and bring the other corner up to the left shoulder and tie the two ends together. Then ensure that you tuck the knot underneath.

3 Add embellishments
Romans would have secured their togas with brooches called fibulae. These were often made of precious metals and decorated with jewels, but you can find cheap alternatives at second-hand shops.

4 Make a belt
Use string or a thin rope to create a belt for your toga. Then simply wrap it around your waist and tie in a knot in the middle. Your Roman fancy dress costume is now complete!

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War Elephants

The tanks of their day, war elephants brought victory to battlefields from Britain to Vietnam

We may not think of elephants as particularly fearsome creatures, but across Asia, Africa and the Middle East, generals were quick to recognise the value of these giant herbivores in battle. However, no civilisation used them as prolifically as the multiple kingdoms of India.

If conventional cavalry were able to shatter lines of soldiers on foot and change the course of battle, then elephants could amplify that. Furthermore, the sight of an elephant charging into the fray, trunk flailing and tusks raised, men crushed beneath its mighty feet, had a psychological impact that would go unmatched until the age of the tank.

First mentioned in the Sanskrit epics of the 5th and 4th centuries BCE, war elephants became such a common sight in Ancient and Medieval India that chroniclers enthused that "where there are elephants, there is victory!" War elephants in India were typically crewed by two to four men on a 'tower', usually armed with bows and arrows, but spears and lances were also common. Covered in bells, flags and bright colours, the elephants could also be armoured with steel plates sewn between layers of cloth, padded leather or chainmail, depending on the wealth of the prince, sultan or Mughal Emperor for whom they fought.

More fearsome still, 6th century CE Chinese traveller Sung Yun recorded swords, scythes, maces and scraps of chain tied to the elephant's trunk. Blades were also attached to the tusks – sometimes dipped in poison – and there are horrific accounts of enemy soldiers being tossed in the air then cut in two by a single flick of the elephant's mighty head.

From the 16th and 17th centuries, elephants were even mounted with firearms such as the terrifying gajnal 'elephant barrel' canon and fielded in combat against the expanding British Empire, before finally falling out of use toward the end of 19th century.

Indian vs African
Larger Indian elephants easily overpowered the now-extinct North African variety.

Plumed helmets
Much like the Greek soldiers they fought alongside, Seluecid war elephants wore plumed helmets.

Ding dong
Elephants wore bells around their necks, possibly to warn the unwary if their drivers lost control of them.

War Elephants in Europe

He had already faced the Persian Empire's war elephants, but it was only when Greek warlord Alexander the Great encountered army of King Porus of the Paurava kingdom of Northern India that he was truly impressed by the potential of pachyderms forming an elephant corps of his own. Through Alexander and his successors, the use of war elephants spread across the Middle East and Greece, then into the emerging superpowers of Rome and Carthage. Though forced to rely on allies or vassal states in India and Africa for a supply of elephants, at least one elephant was used in Julius Caesar's invasion of Britain in 54 BCE (more were shipped over in 43 CE to suppress a revolt), and Carthaginian general Hannibal Barca famously marched his army and their elephants across the snow-capped Pyrenees and Alps from Spain to Northern Italy in 218 BCE.

Hannibal leads his elephants across the Alps

Driver
The driver perched on the elephant's neck, using a wicked-looking hooked goad to control the animal.

Fighting tower
A platform on the elephant's back could carry a crew of four armed with javelins, spears and bows.

You've got mail
The scales on the elephant's chainmail were layered from the bottom because attacks would be directed upwards.

Laminar armour
Made from circular bands of leather or metal, this protected the elephant's neck and legs.

Were African elephants once smaller?

Ancient chroniclers were unambiguous in their preferences: Indian elephants, they wrote, were bigger and stronger than their African counterparts. As a testament to this the Battle of Raphia (217 BCE), the African elephants of the Egyptian king Ptolemy IV Philopater refused to face to the Indian elephants of Greek Seleucid king Antiochus III the Great, being intimidated by their smell, sound and greater size.

This is peculiar because modern African bush elephants are by far the largest of the species, however, the diminutive elephants of the ancient world were in fact the now-extinct North African elephant, then found in Morocco and Algeria.

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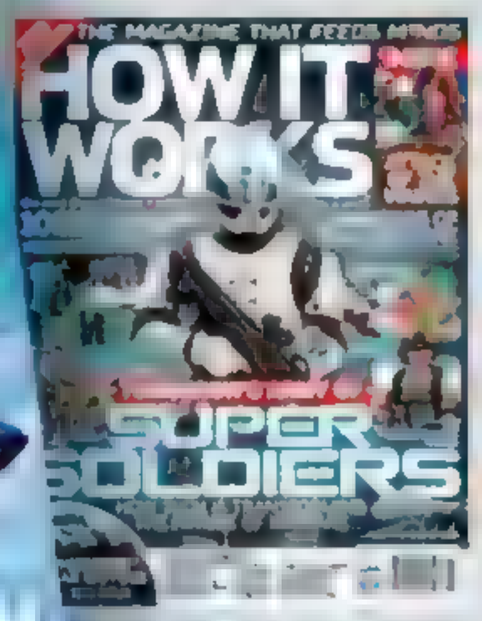

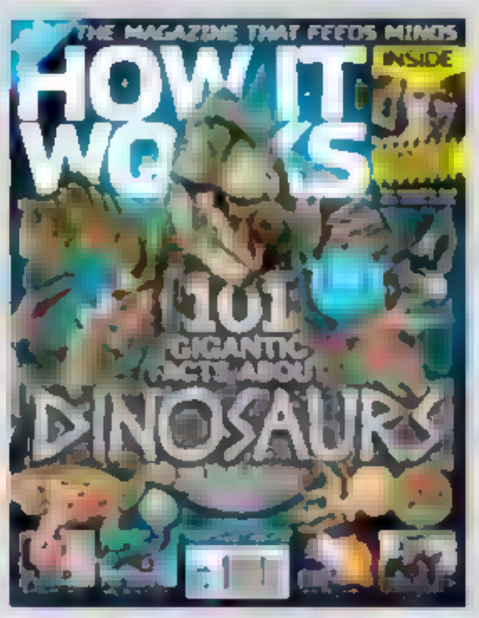

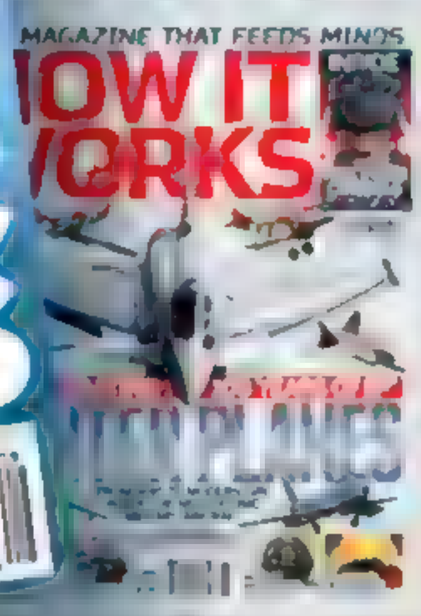

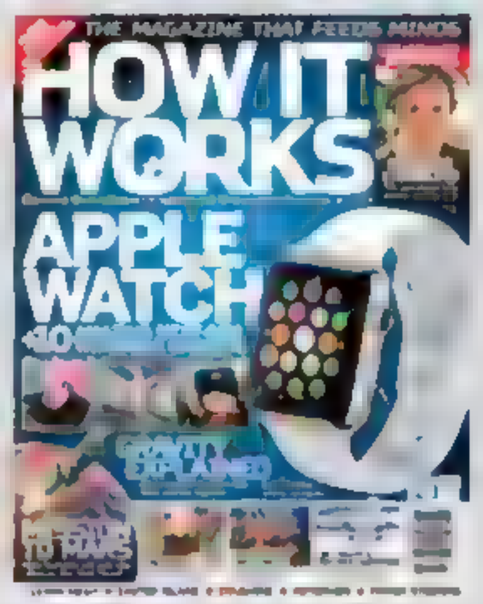

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What is honey hunting?

Discover the terrifying lengths people will go to for their sweet tooth

Honey is the world's most common natural sweetener, and from as early as Palaeolithic times – 2.6 million years ago – our early Hominin ancestors were harvesting it from wild bees. Today, honey hunting is still practised by traditional cultures in Africa, Asia, South America and Australia. However, it's in Nepal where this ancient practice is perhaps at its most dramatic, as at least five different species of honeybee can be found nesting on the formidable cliff faces of the Himalayan Mountains. Still at the heart of life, honey is used in tea by the villagers and sold to Japan, China and Korea for use in traditional medicine. As a testament to its importance, the Gurung people of Nepal even sacrifice a sheep to the mountain gods in hope of a good honey harvest.

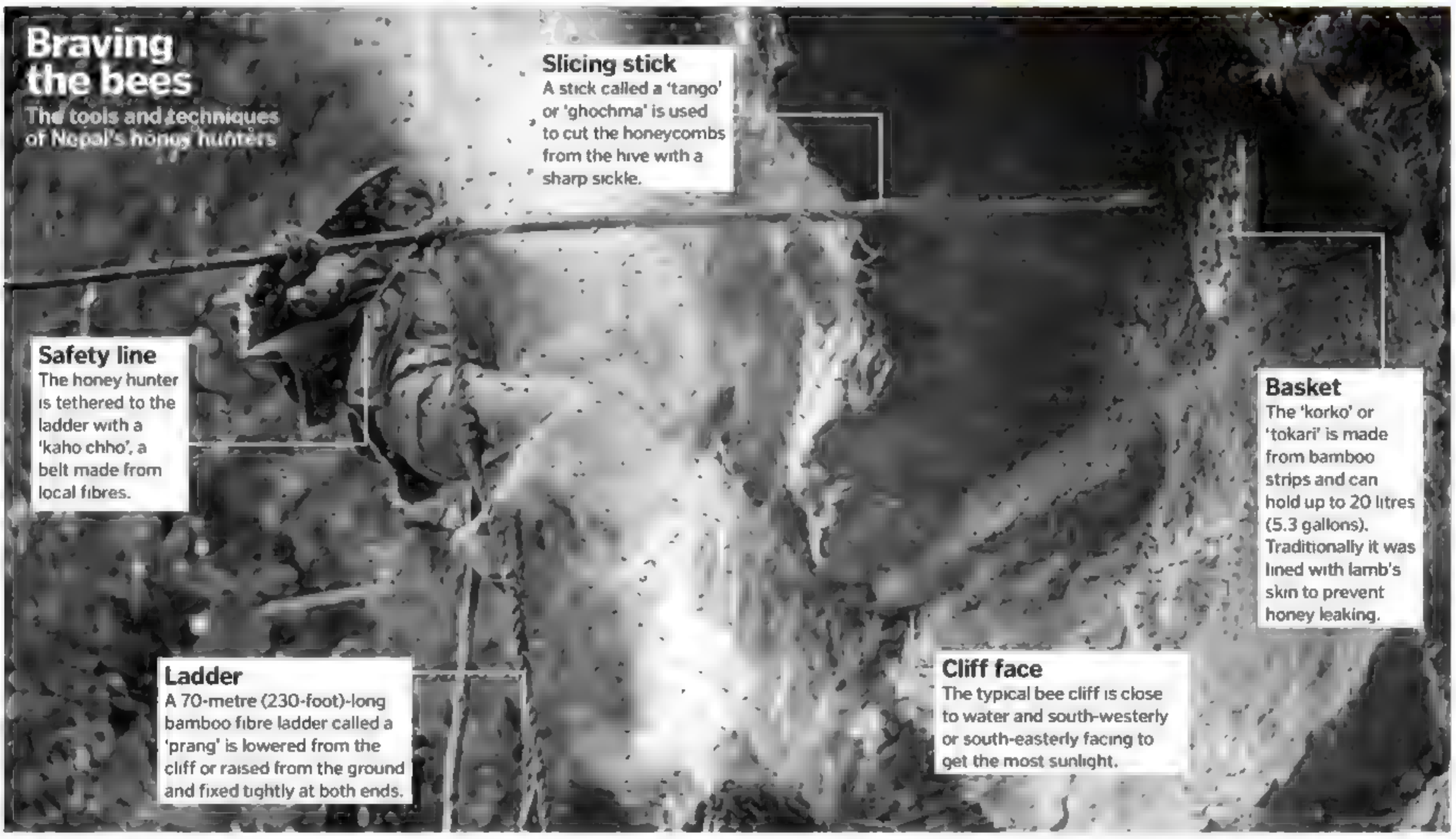
Each region of Nepal has its own distinctive honey hunting technique, but all of them involve lighting a fire under the nest to 'smoke out' the bees, leaving the hive exposed. Men with rope ladders descend the cliff face armed with baskets and poles, while others keep watch, raising or lowering the daring honey hunter's ladder up to 91 metres (300 feet) above the ground. A basket on a pole is held under the hive, while another pole with a sharp blade neatly cuts out the honeycombs, letting them drop into the basket below. Requiring huge skill, patience and self-control, the honey hunter can take up to three hours harvesting just the one hive.

A colony of wild bees in Kathmandu Valley, Nepal

Bee-keeping in Ancient Egypt

Braving the bees

The tools and techniques of Nepal's honey hunters



Slicing stick
A stick called a 'tango' or 'ghochma' is used to cut the honeycombs from the hive with a sharp sickle.

Safety line
The honey hunter is tethered to the ladder with a 'kaho chho', a belt made from local fibres.

Basket
The 'korko' or 'tokari' is made from bamboo strips and can hold up to 20 litres (5.3 gallons). Traditionally it was lined with lamb's skin to prevent honey leaking.

Ladder
A 70-metre (230-foot)-long bamboo fibre ladder called a 'prang' is lowered from the cliff or raised from the ground and fixed tightly at both ends.

Cliff face
The typical bee cliff is close to water and south-westerly or south-easterly facing to get the most sunlight.

BRAIN DUMP

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MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in zoology from Oxford Uni and another in real-time computing. He builds steampunk gizmos and electronic gadgets, and his articles about science, tech and nature have been published around the world.

Laura Mears

Laura studied biomedical science at King's College London and has a masters from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Cheung

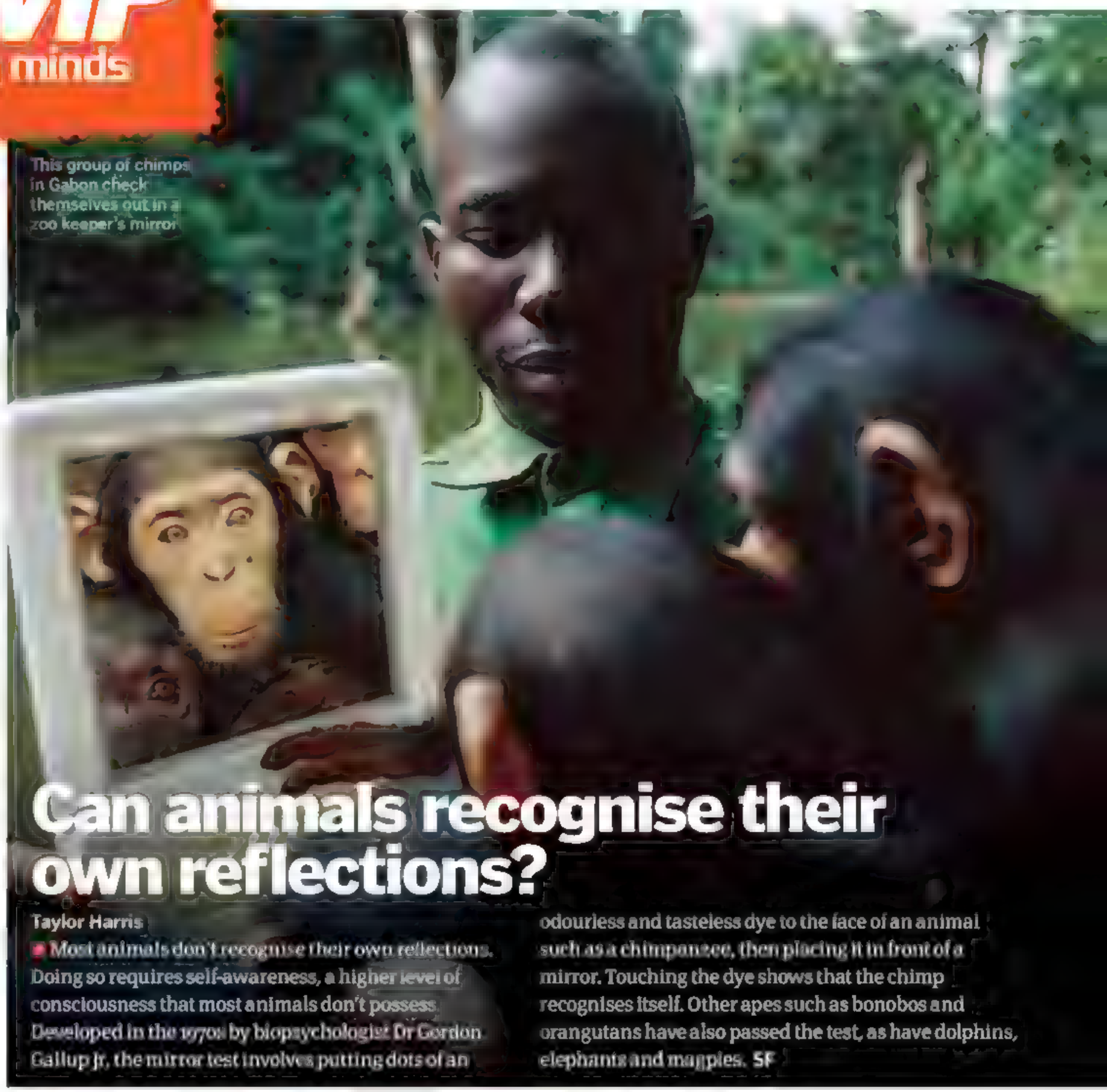
Having earned degrees from the University of Nottingham as well as Imperial College, Alex has worked at many a prestigious institution around the world, including CERN, London's Science Museum and the Institute of Physics.

Sarah Bankes

Sarah has a degree in English and has been a writer and editor for more than a decade. Fascinated by the world in which we live, she enjoys writing about anything from science and technology to history and nature.

Shanna Freeman

Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds her job comes in very handy for quizzes!



This group of chimps in Gabon check themselves out in a zoo keeper's mirror

Can animals recognise their own reflections?

Taylor Harris

Most animals don't recognise their own reflections. Doing so requires self-awareness, a higher level of consciousness that most animals don't possess. Developed in the 1970s by biopsychologist Dr Gordon Gallup Jr, the mirror test involves putting dots of an odourless and tasteless dye to the face of an animal such as a chimpanzee, then placing it in front of a mirror. Touching the dye shows that the chimp recognises itself. Other apes such as bonobos and orangutans have also passed the test, as have dolphins, elephants and magpies. **SF**

The secret to a moving bike's stability remains a mystery.

Why are bicycles much more stable when moving?

Sage Horley

There is no definitive explanation behind a moving bike's uncanny ability to stay upright. Experts agree that it is linked to bikes' ability to steer into a fall and right themselves, with even riderless bikes able to recover from a sideways push. For a long time, it was believed that the wheels created stability through the gyroscopic effect: the tendency for a spinning object to resist movement in certain directions. A second idea was that the direction of travel aligns the bikes wheels a bit like when pushing a shopping cart. Researchers, however, disproved these theories in 2011 by building a bike which negated both effects. A pair of counter-rotating wheels cancelled out the gyroscopic effect and the steering axis lay behind the front wheels, yet the moving bike was still stable. The research team concluded that although both effects may have an impact, neither were vital to a bike's stability. **AC**

The Soyuz spacecraft carries astronauts back and forth from the ISS

What would happen if the ISS had to be evacuated?

Simon Gale

In case of emergency, astronauts on the International Space Station can take refuge or return to Earth on board the Soyuz escape capsules. One or two Soyuz spacecraft remain docked with the station at all times, with each accommodating up to three people. Since the ISS' launch in 1998, its crew have never had to make an emergency return to Earth. In January 2015, a suspected ammonia leak forced American astronauts to shelter temporarily in the Russian section of the ISS. Close encounters with space debris have also forced crew to move to Soyuz as a precautionary measure three times, but no collisions occurred. **AC**

Striped toothpaste comes down to physics and the notion of rheology

How are the stripes in stripy toothpaste made?

Bob Major

Perhaps surprisingly, there are not separate compartments inside a tube of striped toothpaste. To get them in the tube in the first place, the different coloured pastes are merged into a divided nozzle, which keeps the colours separate while dispensing them evenly into the tube from the bottom via a funnelling machine. If you were to cut open a tube of stripy toothpaste, you'd see that the stripes are thicker inside. It's only when you squeeze the tube that they become thinner as they flow out the nozzle. The reason they flow at the same speed and consistency is down to the scientific study of the flow of matter. In scientific terms, the stripes all have the same rheology. This means that they keep the same thickness and flow in the same way under different pressures, so they keep their positions and remain as stripes in the paste. **LM**

Why aren't keyboard keys arranged alphabetically?

Robin Wild

That's because it's less efficient. An alphabetical keyboard would put A and E on the left and middle of the top row, and T on the left of the bottom row. These are the most uncomfortable places for touch typists to reach, for some of the most common letters in English. The alphabet is a random sequence of letters and there's no reason to suppose it has an advantage for keyboards. There are patterns that are theoretically more efficient than QWERTY. These layouts never took off, but alphabetic order is demonstrably worse than QWERTY. **LV**

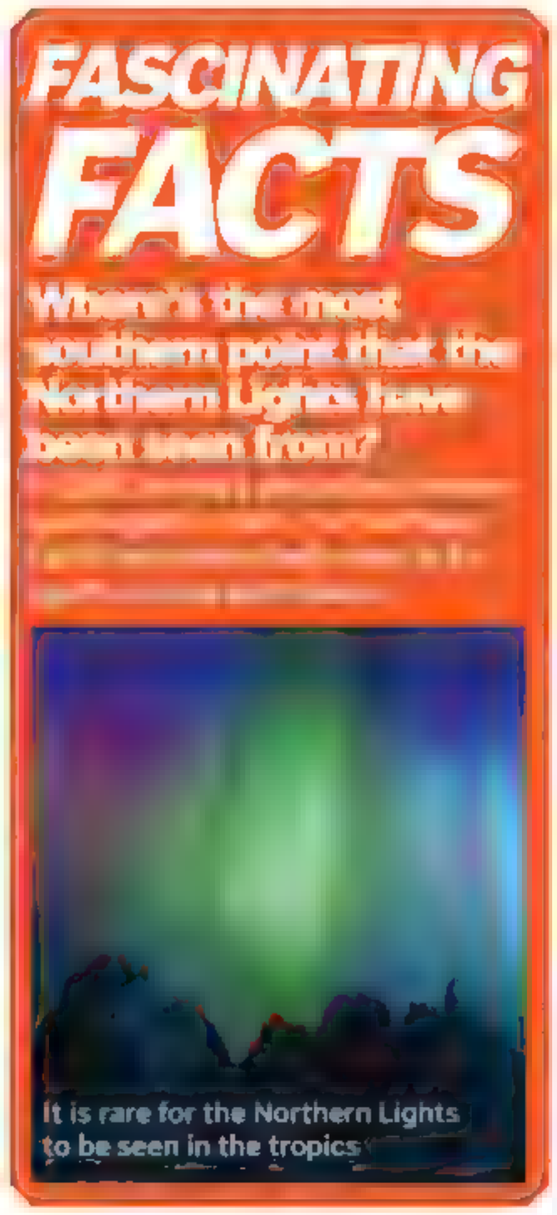
Early typewriters used lots of different key layouts until QWERTY eventually took over

Why do we swing our arms when we walk?

Rufus Gill

It was originally thought that arm swinging might help with balance, but so far the science has not managed to demonstrate enough evidence to prove that idea. However, there is another possible explanation. Analysis of oxygen consumption when people walk and swing their arms reveals that the swinging motion actually helps to save energy. One study found that when people swung their arms as they walked, they used up to eight per cent less oxygen than when they kept their arms by their sides, indicating that their muscles were burning less fuel. **LM**

Swinging your arms as you walk helps to conserve energy



BRAIN DUMP

What are tonsils for?

Nora Hicks

We each have four sets of tonsils. The palatine tonsils are the easiest to spot, with one either side of the back of the mouth. Then there is the lingual tonsil behind the tongue, and the tubal tonsils and the adenoids on the roof of the mouth. They are part of the lymphatic system, which is a network of vessels used by the immune system to patrol and defend the body. Together they form a defensive ring that guards the entrance to your lungs and digestive system. Inside the tonsils, powerful cells of the immune system can detect infection early, and mount a rapid response. **LM**

Why do trees only grow to a certain height?

Dylan Storer

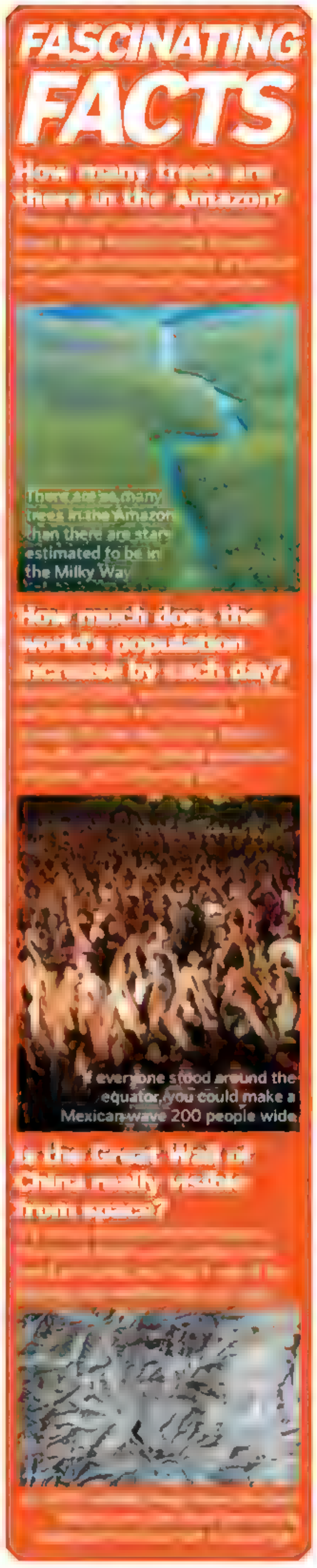
A number of factors can limit tree growth, but water transport is what puts the ultimate cap on their height. The taller a tree, the further it needs to carry water and the harder it needs to work against gravity in doing so. Although trees gain an advantage in growing taller than their neighbours and capturing more sunlight, beyond a certain point it costs them more energy-wise to keep their uppermost leaves hydrated than they gain from the additional light, causing them to stop growing. Other environmental factors such as nutrient or water limitation and climate, also affect how tall a tree can grow. **AC**

Mist and steam often get confused, but have very different properties

What's the difference between steam and mist?

James Thornton

Steam is water in a gaseous state, whereas mist is water in a liquid state. The two consist of very different properties. These properties mean that the tiny water droplets that make up mist are suspended in the air, while the water molecules that make up steam cannot stick together in the form of water because they are in such a high energy state. When water is heated to boiling point it evaporates as steam, which is the reason why steam is always warm. On the contrary, mist is produced in cold conditions when water in the atmosphere condenses and small droplets of water form. **SB**

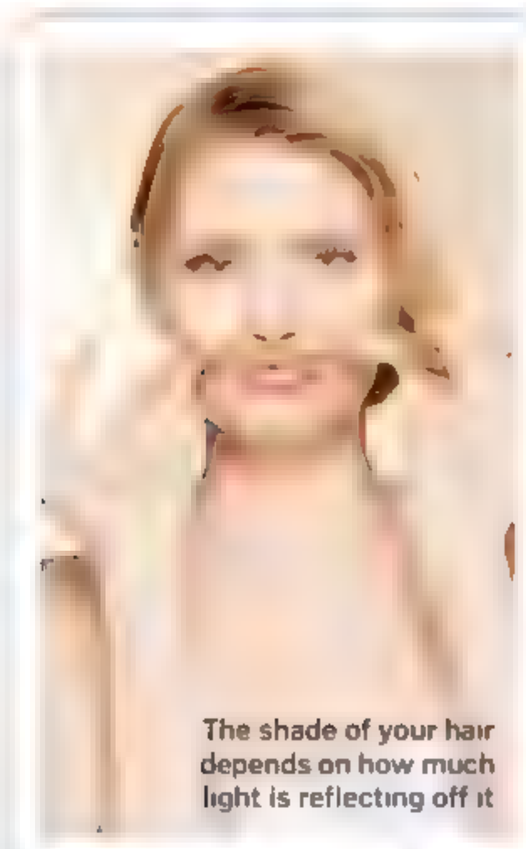


Can a spaceship be repaired in orbit?

Neil Riley

Astronauts and cosmonauts aboard the International Space Station perform spacewalks regularly to make repairs. In early 2015, two American astronauts spent about 20 hours over the course of three spacewalks to install cables. NASA is also testing technology on the ISS that will eventually be used to repair existing satellites in orbit, using both humans and robots. This technology is part of a campaign to enable spacecraft repair while in space, which will help further exploration beyond our current capabilities. The Apollo 13 mission in 1970 required the astronauts aboard to make a life-saving repair so they could return safely to Earth after an on-board explosion aborted their mission to the Moon. At the time, they were about 322,000km (200,000mi) from Earth. So in short, spacecraft repairs in orbit are definitely possible. **SF**

The visor of US Astronaut Reid Wiseman reflects astronaut Barry Wilmore during their spacewalk outside the ISS to make repairs

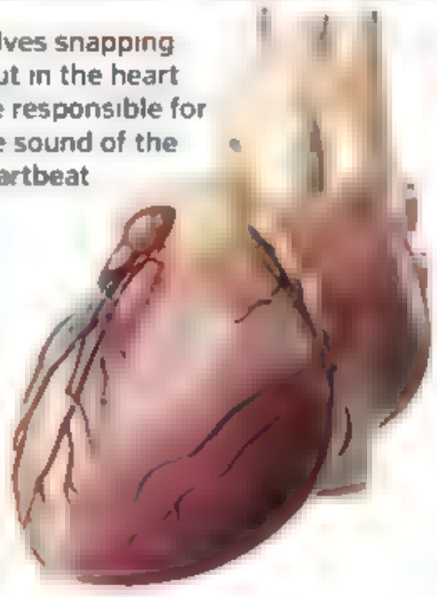


The shade of your hair depends on how much light is reflecting off it

Why does hair get darker when wet?

Chuck Palmer

Hair is lighter when it's dry because light bounces off of the many surfaces of its strands, sending back numerous waves of light that our eyes perceive as lighter colours. Hair that's wet is smooth and sticks together. When light strikes it, more is absorbed and the light bounces around. That means less light is reflected off the hair and your eye perceives it as darker. **SF**



Valves snapping shut in the heart are responsible for the sound of the heartbeat

Why does your heart pump twice for every beat?

Joseph Newell

The human heart has four chambers, two atria at the top of the heart, which collect blood returning from the body and lungs, and two larger ventricles at the bottom, which pump blood back out again

The heart has its own biological pacemaker, which triggers a rhythmic electrical wave that spreads across the muscle. It starts at the top and travels down the walls of the two atria, making them squeeze and transferring the blood into the ventricles. Valves then snap shut to prevent the blood moving back, making the 'lub' sound of the heartbeat

The electrical impulse moves down to the bottom of the heart through specialist cells in the middle, and then comes up in a wave, making the ventricles contract and forcing blood towards the body and the lungs. Then a second set of valves snap close, making the 'dub' sound of the heartbeat. **LM**

Why do lips get chapped?

Mona Franks

When lips lose moisture, the skin covering them can become tight and eventually crack or become flaky, sometimes resulting in sore and even bleeding lips. Unlike other parts of our body, our lips do not contain oil glands, which means they are more likely to become dry. Other factors then exacerbate the situation. So, a lack of moisture makes matters worse, whether this is weather induced or a failure to moisturise lips manually, and frequently licking lips actually removes moisture too. Extreme weather conditions, such as cold or dry air, wind and Sun exposure, strip the lips of moisture, therefore also lead to chapped lips. **SB**

Use a lip balm containing petroleum or beeswax to aid chapped lips

BRAIN DUMP

Why do cats go crazy for catnip?

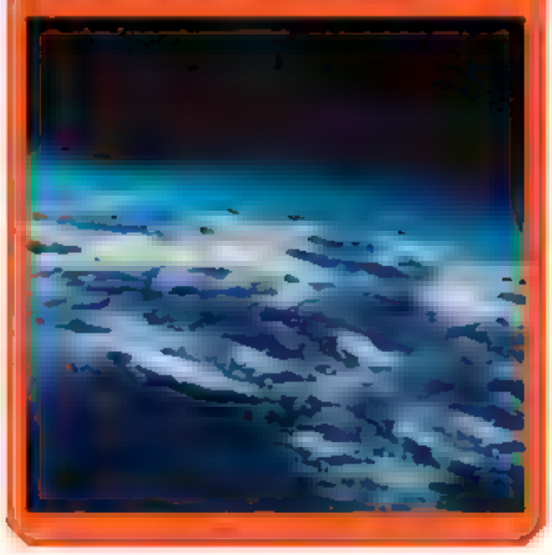
Alicea Hitchcock

There is an oil found in the catnip plant (nepeta cataria) called nepetalactone. Researchers believe that when this oil enters a cat's nasal tissue, it binds to protein receptors that stimulate sensory neurons. This leads to a response in neurons in a certain part of the brain known as the olfactory bulb which projects to other brain regions; regions that not only mediate emotional responses to stimuli (consequently causing a behavioural response), but also regulate neuroendocrine responses, making the cat react to an artificial cat pheromone. It doesn't affect all cats, but many react by rolling around, flipping over, becoming hyperactive and sometimes acting aggressively, before experiencing a come down ten minutes later. **SB**

FASCINATING FACTS

Where does space begin?

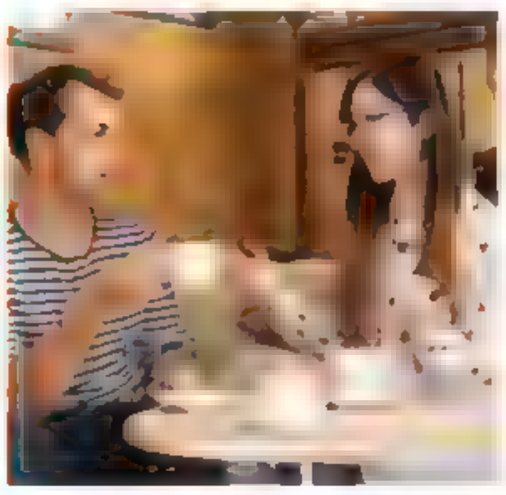
There is no consensus on where space begins, but the most widely used definition (set by the International Astronautical Federation) places this border at 100 kilometres (62 miles) altitude.



What are black box flight recorders made from?

Janine Lloyd

Cockpit flight recorders are enclosed in a steel or titanium box (which is painted orange to make it easier to find). Inside that there are some racks of very rugged electronics, but most of these don't actually need to withstand a plane crash, as long as the tapes or memory chips containing the actual data do. They are stored in an inner armoured steel case coated in a flame retardant paint and lined with several layers of insulating materials. Blocks of paraffin wax are used at various points as thermal barriers. In a fire, the paraffin melts and absorbs some of the heat. **LV**



Why does coffee make me dehydrated but tea doesn't?

James Hoare

Caffeine in general – whether it's in tea, coffee, or soda – is definitely dehydrating However, when you consume these beverages you're also consuming water, which seems to ultimately counteract any dehydrating effect. Studies have given us conflicting information, though there appears to be a limit. According to the Mayo Clinic, if you consume more than 500 milligrams of caffeine per day on a regular basis, you could be at risk of dehydration. As long as you drink a variety of beverages and drink whenever you're thirsty, you shouldn't have a problem. Although it might seem that you have to urinate more frequently when you drink coffee, you'd probably have to go just as often if you were drinking an equivalent amount of plain water. **SF**

Inside a neon light, gas is ionised, enabling it to conduct electricity.

Can gas be a conductor of electricity?

Roger Harris

Gases are generally poor conductors of electricity. Good electric conductors, such as metals, have loosely bound electrons that can move freely when exposed to an electric potential, producing a current. Gases have no free electrons and therefore do not conduct electricity easily. Under a strong enough electric potential or in extreme heat, gases can, however, become ionised, breaking apart into charged ions and electrons to create a different state of matter known as plasma. This occurs, for instance, during a lightning strike or inside a neon light. Unlike gases, plasmas are good conductors of electricity. **AC**

Why does water taste colder after eating something minty?

Francis Schmidt

Cold-sensitive nerves are coated in tiny pores known as TRPM8 receptors, which under normal conditions, are firmly closed. When the temperature drops, the channels open, and positively charged ions flood into the nerve cell triggering an electrical signal that travels towards the brain. Although mint does not actually reduce the temperature of the mouth, it contains an ingredient called menthol, which can stick to the TRPM8 receptors. This makes the receptors more sensitive than before, meaning that if you drink a glass of cold water the channels will open more easily, making it feel colder. **LM**

How do photochromic lenses get darker in bright light?

William Laver

Embedded in the lens glass are crystals of silver halide. This is normally transparent but when the glass is struck by UVA rays from sunlight, it causes the glass to release electrons that bind with the silver ions in the crystals. This converts them from transparent ions into atoms of elemental silver, which is opaque. The silver atoms are constantly reacting with the halide ions to turn back into silver halide, but as long as the ultraviolet light is strong enough, it produces silver atoms faster than they can react back and so overall the glass gets a darker tint. Indoors, away from the ultraviolet, the atoms gradually all react back again and the lenses revert to clear. Because this reverse reaction is temperature dependent, photochromic lenses take much longer to become clear in cold weather. Plastic lenses work on a similar basic principle but use organic dye molecules called naphthopyrans instead of silver halide. **LV**

Car windscreens block ultraviolet, so most photochromic lenses don't work very well while driving

The vacuum slows heat transfer, so hot things stay hot and cold things stay cold

How exactly do vacuum flasks work?

Miranda Nash

Heat can be transferred in three ways: conduction, convection or radiation. Conduction involves atoms physically colliding with each other to transfer their kinetic energy. Convection does this too, but also takes advantage of the fact that hot fluids have lower density and so will rise, taking their heat with them. Vacuum flasks have a double glass wall and the gap in the middle is a vacuum. This means it contains no atoms that could transfer heat across the gap by conduction or convection. That leaves radiation, but the sides of the glass are also silvered, which helps to reflect radiated heat from either side. **LV**

New Brain Dump is here!

Don't miss issue 27 of **Brain Dump**, the digital sister magazine to **How It Works**, when it lands on the virtual newsstand on 6 August. You'll find out how wolves evolved into dogs, why food turns bad and the answer to the question: what would happen to our bodies if the force of gravity doubled? Also in this issue: the appendix explained and how to walk on water! Every edition is packed with stunning images and fun facts to entertain your friends and family with. Download the new issue of **Brain Dump** at the beginning of every month from iTunes or Google Play. If you have a burning question, you can ask at **www.facebook.com/BraindumpMag** or Twitter – the handle is **@BrainDumpMag**

Home Robots

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1 A mini transformer you can reassemble

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www.owirobot.com

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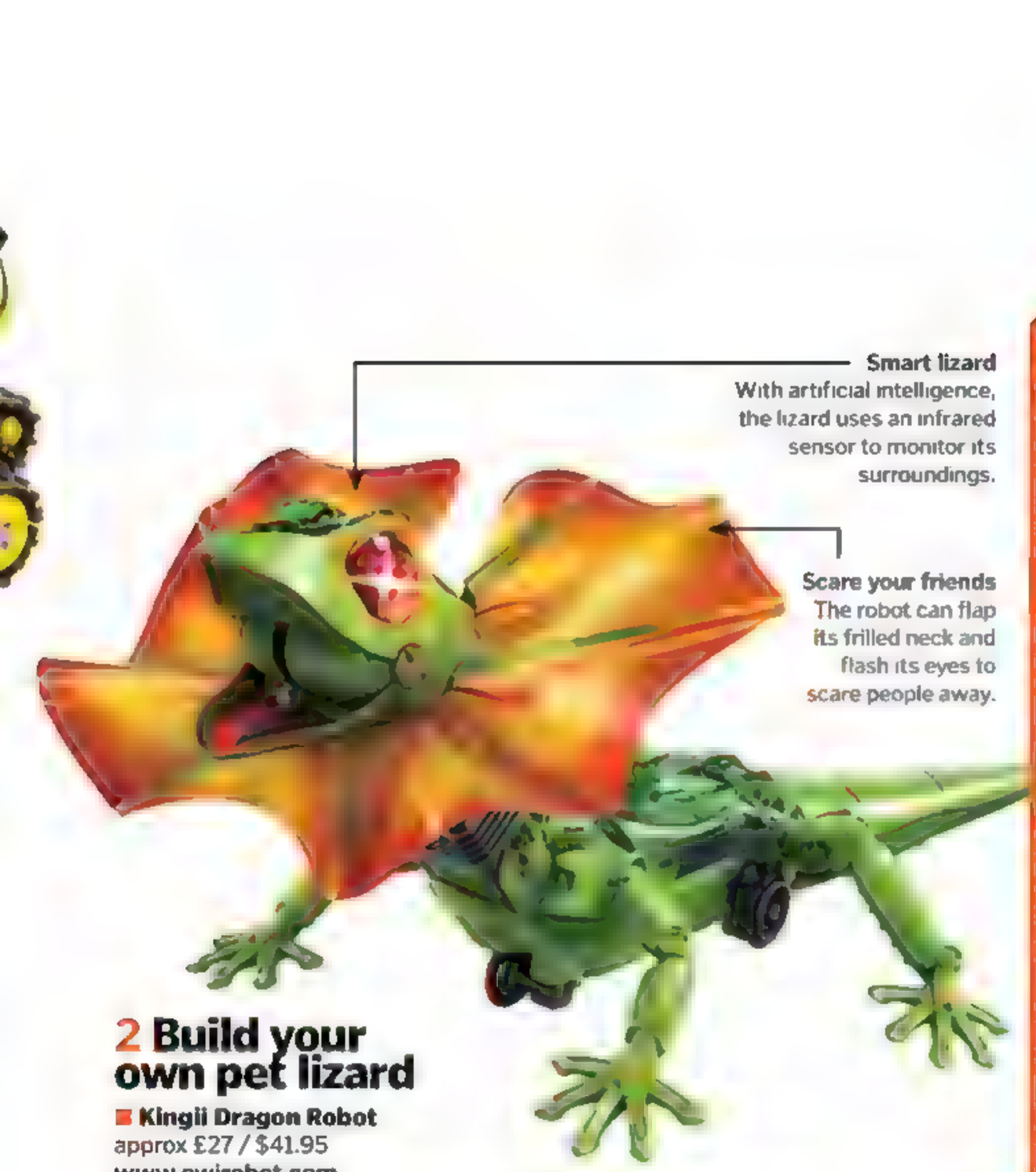


2 Build your own pet lizard

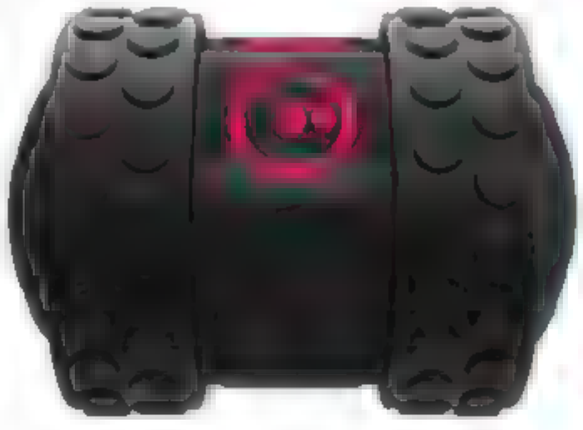
Kingii Dragon Robot
approx £27 / $41.95
www.owirobot.com
Although modeled on the Australian chlamydosaurus kingii (frilled-neck lizard), this little robot is much more fun to play with. It comes disassembled so you can enjoy building it yourself before experiencing its smart artificial intelligence first-hand. An infrared sensor helps the robot monitor its surroundings. When switched to 'escape' mode, if the robot feels threatened it will open its jaws, spread and flap its frills, and flash its LED eyes in a threatening manner, before turning around and scurrying away. In 'follow-me' mode, it will assess danger by spreading its frills to bluff the attacker, but approach if the coast is clear

3 Your smart eight-legged friend

Vex Robotics Strandbeast
£89.99 / $89.99
www.hexbug.com
You first need to snap together over 400 different components to build this jumbo-sized robot insect, helping you to understand how it works before you see it in action. A centralised computer acts as the brain, signalling for the motors to activate the gears which then start moving the eight legs in unison. The brain can be controlled using a remote control or work autonomously using sensors that reflect infrared light to help it avoid bumping into its surroundings. By flipping switches on the brain, you can choose from 64 different programming modes that determine how the robot reacts when its sensors are activated.

4 Perform cool tricks and race your friends

Sphero Darkside
£99.99 / $129.99
www.sphero.com
Not only can the Sphero Darkside travel at speeds of up to 22.5 kilometres (14 miles) per hour, it can also perform amazing tricks, including spins, flips and more. Its interior electric motor can be controlled using an app on your phone, which wirelessly connects to the robot via Bluetooth. Two sets of tires and hubcaps are supplied for customisation and extra grip, or you can remove them to drift on smooth surfaces. Crashing isn't a problem thanks to the durable polycarbonate shell and the built-in LEDs mean you can drive at night as well.



EXTRAS

BOOK

How AI Works: Book Of Robots

APP

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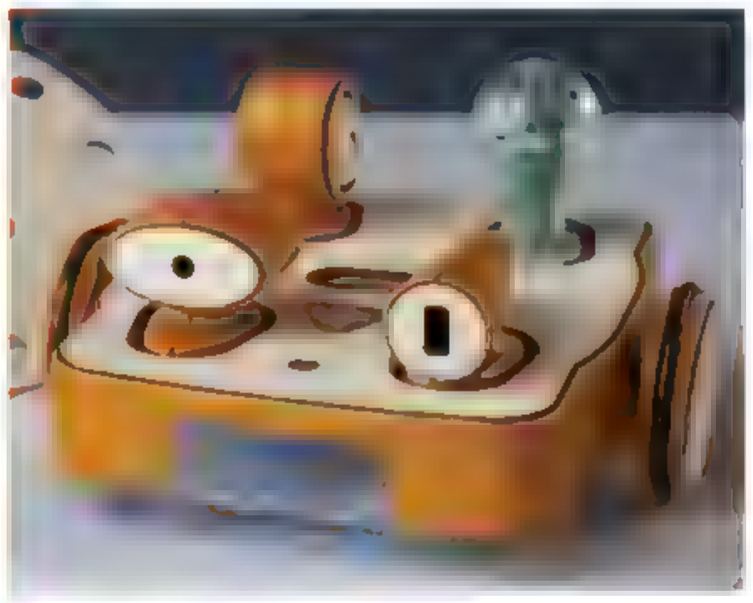
your projects with others and a blog featuring the latest

5 Build your own programmable robot

Lego Mindstorms EV3
£299.99 / $349.99
www.lego.com
Bring your Lego creations to life with this customisable robotics kit. The main component is the programmable EV3 Brick, which acts as the main power station for your robot. This can connect to your mobile device via Bluetooth to enable control from an app, or be fitted with colour and touch sensors for autonomous control. To this you can attach a series of motors and any of the 550 Lego Technic pieces supplied to build your creation. The app provides building instructions and ready-made downloadable programming files for several different robots. Alternatively, you can program the robot from scratch with a simple icon-based interface



6 Learn basic programming skills

KIBO
approx £145 / $229
www.kinderlabrobotics.com
Designed for young children aged four to seven, the KIBO kit helps teach the very basics of robotics and programming. First, the child can assemble the robot by attaching a series of components, including wheels and sensors, to the main body and then decorate it as they wish. They can then line up a series of wooden blocks to create a sequence of instructions, such as turn right or make a sound. By scanning the barcodes on these blocks the KIBO robot will start following the instructions as soon as its main button is pressed and can even respond to clapping sounds too.

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Split water

Conduct an electrolysis experiment to split water into hydrogen and oxygen

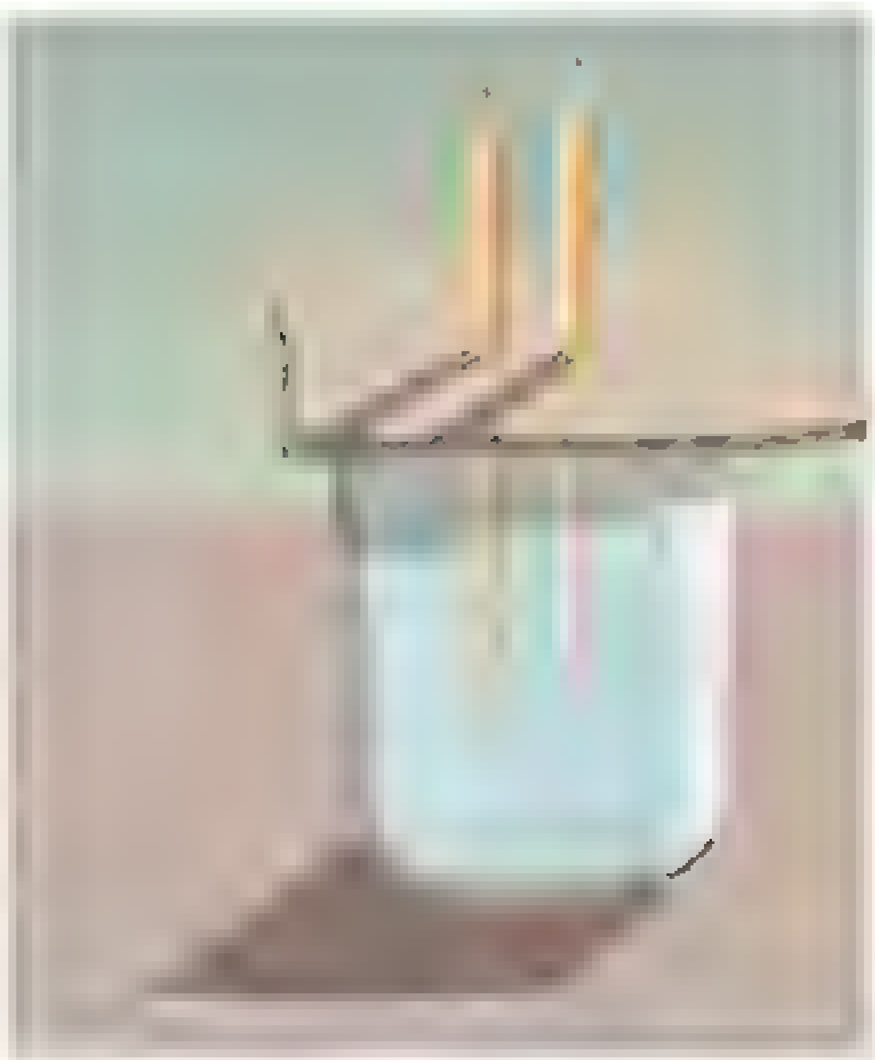
1 Fill your beaker

Take a beaker or a glass and begin to fill it with warm water. The water doesn't need to be boiling for this experiment to show some results; however, high temperature electrolysis is being investigated as a more efficient means of producing hydrogen and oxygen, than room temperature electrolysis. The beaker only needs to be half full.

DON'T DO IT ALONE

2 Prepare your pencils

Now take two standard pencils and sharpen both of them, top and bottom, so that the graphite is clearly exposed at each end. You may need to remove the erasers and metal sleeves depending on the type of pencil that you use. The graphite that is found in pencils is vital to this project, as it conducts electricity but doesn't dissolve in water. This will allow the pencils to act as electrodes in this experiment.

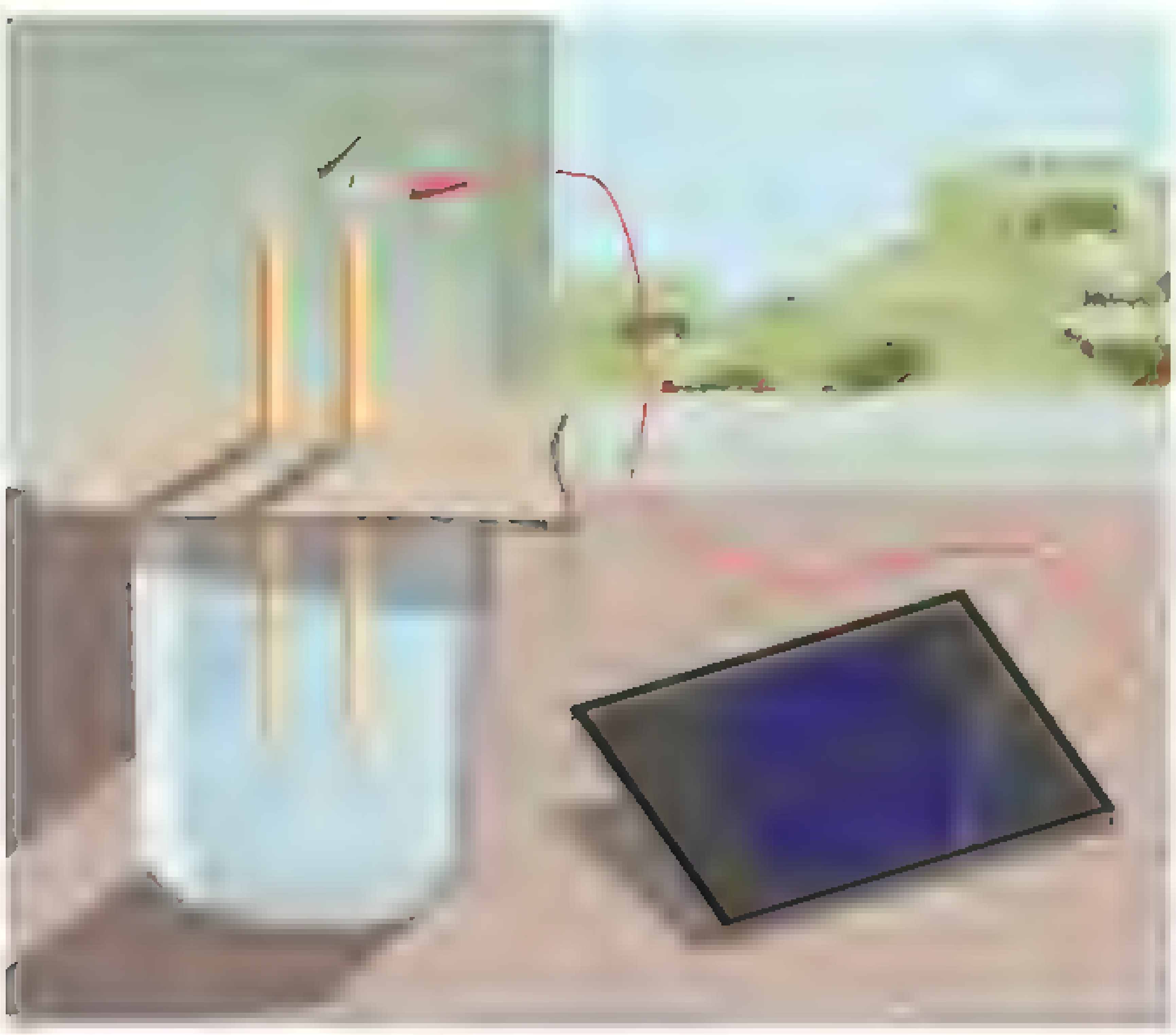


3 Position the electrodes

Take a piece of cardboard that is big enough to lie on top of the beaker without it falling in. Pierce two holes into the centre of the cardboard and push the two pencils through the holes so that their graphite tips are fully submerged. For the experiment to work, the graphite must not be touching the bottom of the glass. Make sure the pencil holes are tight, so that the pencils won't move.

4 Start splitting water

Complete the assembly by connecting each pencil to a six or nine-volt battery with an alligator clip, making sure the clips are securely clamped onto the graphite. If you don't have any alligator clips, two pieces of wire with around 2.5 centimetres (one inch) of insulation removed from each end will suffice. If you do end up using wire, make sure you tape it in place.



5 Make the process sustainable

There are a number of ways you can build on the design that you have already created. To take your electrolysis experiment to the next level, add an electrolyte to the beaker water in the form of table salt. Check to see if more bubbles form than without the electrolyte (be careful as small amounts of chlorine gas may form). You can even make your experiment completely sustainable by using solar cells instead of a battery.

In summary...

As soon as you complete your setup by connecting the pencils to the battery, you will notice that bubbles start to form around the tips of the submerged pencils. These bubbles are actually the elemental components of water (hydrogen and oxygen), which have been split by the electricity as it passes through the water between the two pencils.

NEXT ISSUE

Build a solar oven

Harness the power of the Sun to cook something delicious with this simple solar oven

1 Modify your pizza box

With the help of an adult, cut into the lid of the pizza box, creating a large flap. To do this, cut along three sides of the box, making sure you leave enough cardboard around the edge of the lid. The flap you have created needs to be folded out so that it stands up even when the lid of the box is closed. Cover the flap's inner side with aluminium foil and secure it with tape; this will reflect the Sun's rays onto the food.

2 Insulate the solar oven

Create an airtight window in your box using transparent plastic wrap, making sure it has a strong seal to prevent air entering or escaping. Using black construction paper, line the bottom of your box. To insulate your oven, take some newspaper and roll it up so that it can be placed in the bottom of the box, around the sides. Tape it down in order to create a border around the cooking surface.

3 Start cooking!

The optimum time to use your oven is when the Sun is at its strongest, which is typically between 11am and 3pm. Place it in direct sunlight, and adjust the aluminium-coated flap so that it reflects the largest possible amount of sunlight onto the food. To maintain this flap angle, use a ruler to hold it in position. Alternatively, the entire box can be angled using a rolled up towel or another object.

In summary...

This type of oven is known as a collector box, as it functions by trapping the sunlight's heat. This works because the foil layer reflects the Sun's rays, bouncing them into the opening and through the plastic wrap. This heats the air trapped inside to a temperature in the region of 93 degrees Celsius (200 degrees Fahrenheit).

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Whether you're at a festival or simply out for the day, keeping your electronics charged is a must. This powerful solar charger is water and shock resistant, and will charge a variety of devices with ease

Letter of the Month

Why does running cause a stitch?

Dear **HIW**,
Being a runner, I've always wanted to know the science behind a stitch, and whether there is any way to prevent or stop them from happening?
Titus MacDermot (aged 11)

That's a great question, Titus. Considering the widespread nature of this problem, there is actually very little information on what causes a stitch. What we do know is that a stitch is more likely to occur in people who haven't warmed up properly, or have eaten too close to the start of their exercise.

There are two theories relating to the process that takes place to produce a stitch. The first is that when we exercise, our blood travels away from the diaphragm and concentrates in the limbs. Scientists believe that this causes the diaphragm to cramp, which causes the pain of a stitch to be felt. Another theory focuses on the process of digestion, suggesting that a stitch is caused when our bodies struggle to digest certain liquids. This results in the gut pulling on the connecting diaphragm ligaments, causing the pain of a stitch.

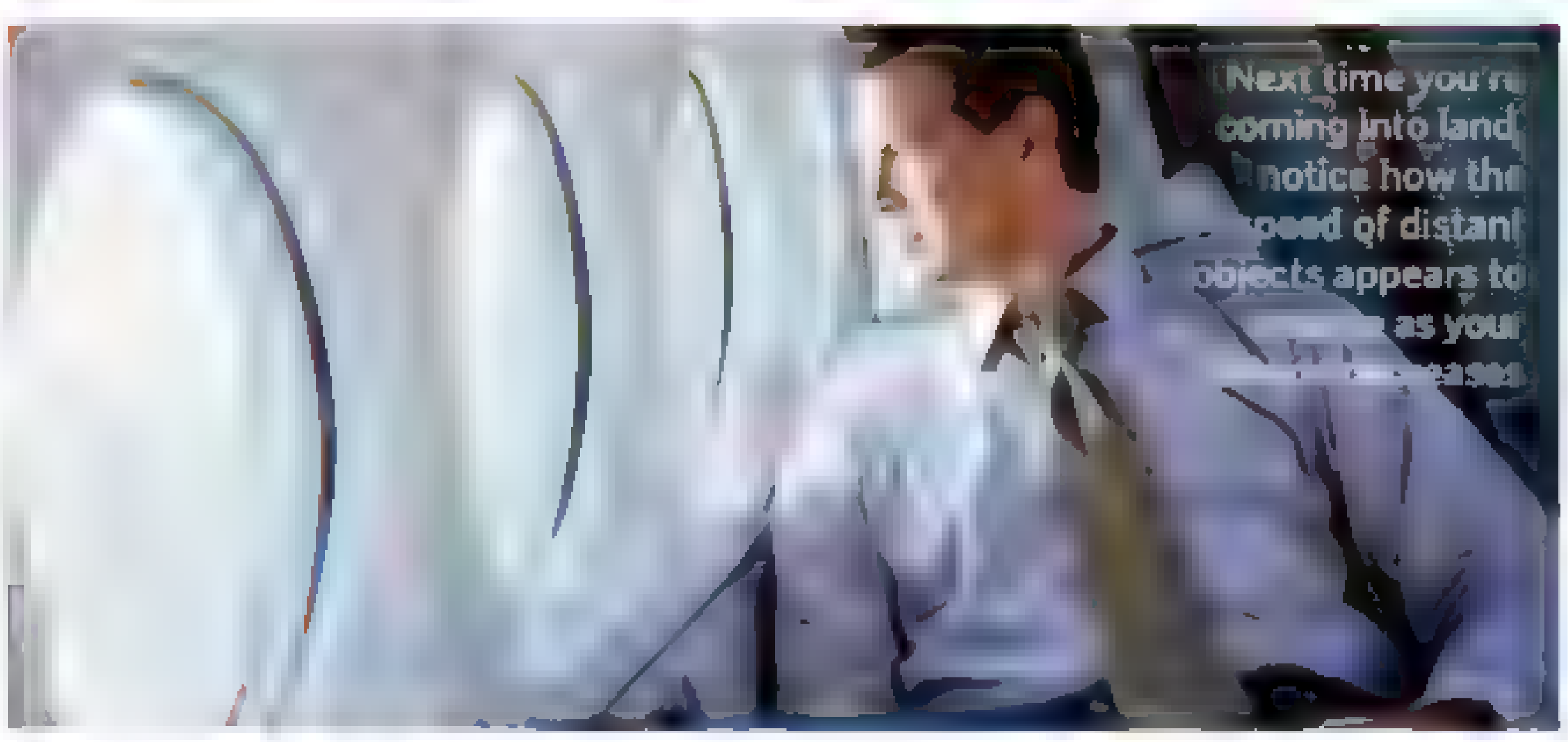
To prevent a stitch and to help release it when it happens, you should try walking for a while and focus on regulating your breathing. Bending to touch your toes for a few seconds is also said to help ease the pain.

The illusion of speed

Dear **HIW**,
I love reading the magazine each month. After I've read it, other family members get a look and then eventually it goes to school and helps the children with their studies!

Why is it that when flying at several hundreds of miles per hour, the ground below seems to be moving past so slowly?
Many thanks,
Jeff Jacobs

This phenomenon is partly down to an optical illusion created by our eyes when they view something in the distance. The retinal images created by viewing a small, close object when you pass it at a slow speed are the same as those created by a large, distant object when you fly past it quickly. This is why it is hard for us to judge speed effectively, and why we need to have speedometers fitted in our cars; we are poor judges of absolute speed and distance.



Bullet ricochet

Dear **HIW**,
I have a question that I would really like answering.
Can a bullet bounce around in a solid metal room really fast, like in the movies?
Thanks
Tom Foale


When a bullet experiences a series of ricochets, it will quickly become deformed

This is one of the many occasions in which the movies mislead us! While it is definitely possible for a bullet to ricochet off a hard surface, each time it does so it loses speed. This means that it won't continue to bounce around at a lethal pace, and would eventually lose enough speed to stop ricocheting.

Our Sun's mass makes up 99 per cent of the mass in our Solar System

"After I've read How It Works, it goes to school and helps the children with their studies"

The big question

Dear **HIW**,
I really can't stop reading your magazine since I got a subscription; it's my favourite thing to read! Like many people, there's quite a lot about space that I don't understand, and my question is about gravity. Why does the Sun have gravity 28 times the strength of Earth's?

Thank you very much,
Jamie Andrews (age 13)

According to Newton's law of gravitation, an object's gravity is directly related to its mass – the amount of matter it contains. The reason why the Sun's gravity is so large compared to Earth's is due to its much larger mass, estimated to be over 333,000 times that of the Earth. Objects with a larger mass are known to exert a larger gravitational force, which explains why the Sun's gravity is many times stronger than Earth's.

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Thanks to @**HowItWorksmag** for their great coverage of the @NASA Hubble on its 25th birthday

Antarctica is the driest continent on Earth with the lowest annual rainfall #howitworks

My Saturday night in is sorted #reading #dinosaurs @howitworksmag

@**HowItWorksmag** Subscription arrived yesterday. Thanks for the great magazine. A ton of great reading for all of us every month!

I wonder who was the first person to [illegible] soaring high above & think it a good idea to capture it and lock it [illegible]

@SamHarrisOrd
Just learned that I have 2.6% Neanderthal DNA. I will now blame all of my personal deficiencies on [illegible] (Average European = 2%)

[illegible] can say that their [illegible] lasted 24 hours and [illegible] leapsecond

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• Your body is around 60% water

• Water at the top of Everest can boil at 72°C

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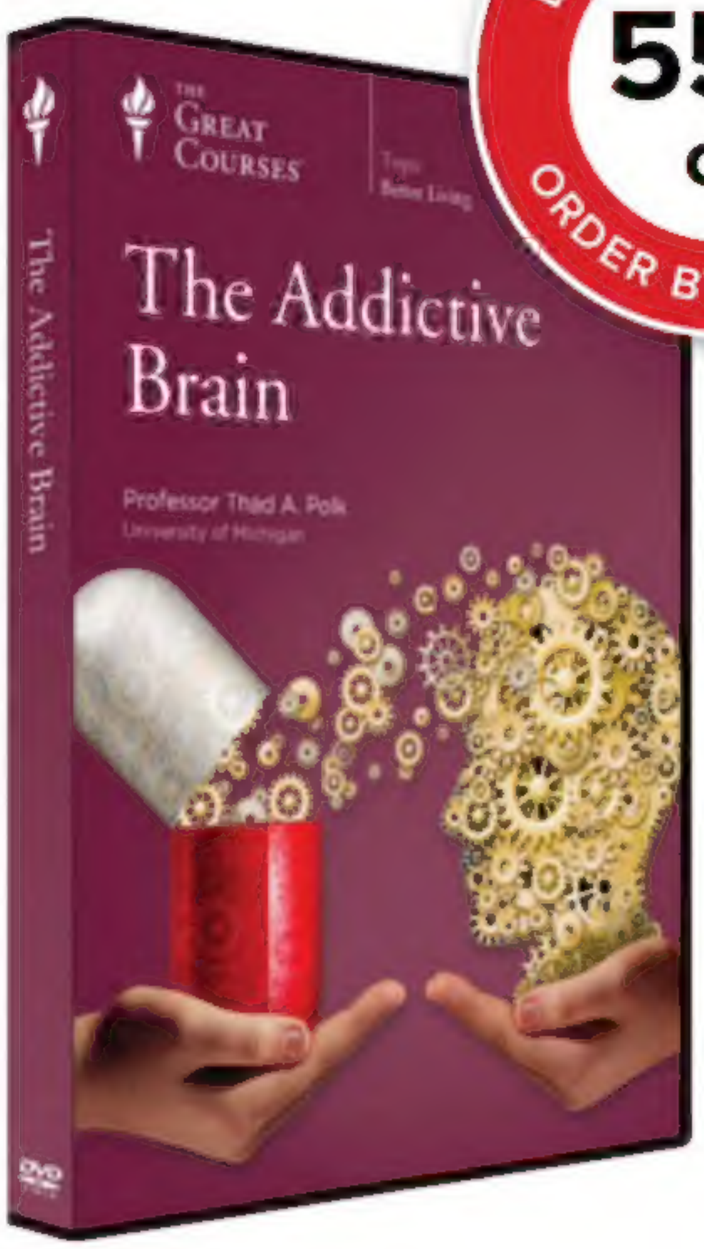

What Happens in the Addictive Brain?

Addiction touches us all. Whether it's a friend who can't quit smoking, a colleague afflicted with alcoholism, or a relative abusing prescription drugs, we all know someone who suffers from some form of addiction—we may even have an addiction ourselves. But what actually happens to the brain on drugs, and why do addicts behave the way they do? What can neuroscience tell us about addiction?

The Addictive Brain explains what happens at a neural level when someone sips coffee, smokes a cigarette, snorts cocaine, and more. Taught by Professor Thad A. Polk of the University of Michigan, these twelve eye-opening lectures reveal what happens when drugs enter the brain and the way drug molecules induce pleasure and shut down the ability to make sound decisions. You also investigate addictive behaviours such as gambling, binge eating, and excessive video gaming—as well as potential treatment options. Insights into the underlying mechanisms of addiction can help motivate people to seek treatment, and can provide friends and loved ones with a deeper understanding.

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